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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 746

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 18, 1919

THE SUGAR-CANE MOTH BORER

By

T. E. HOLLOWAY and U. C. LOFTIN
Entomological Assistants, Southern Field Crop Insect Investigations

WITH TECHNICAL DESCRIPTIONS BY
CARL HEINRICH

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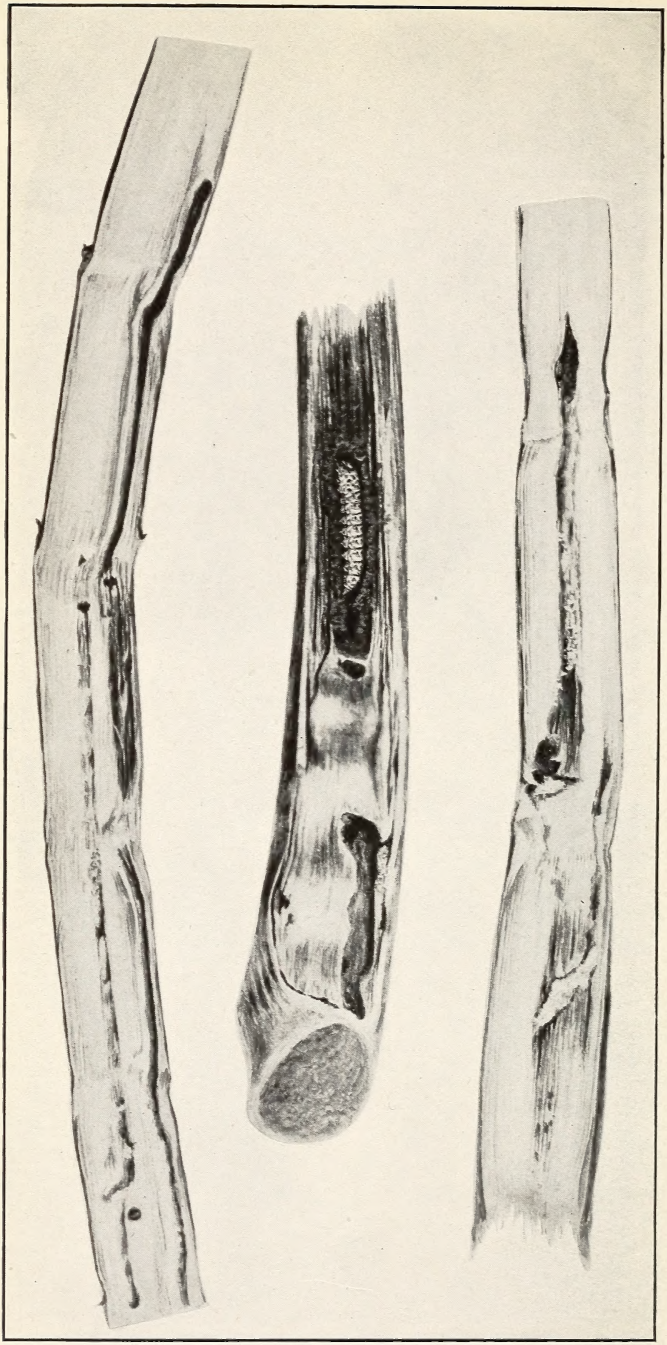
WASHINGTON
GOVERNMENT PRINTING OFFICE
1919



INTERIOR OF STALKS OF SUGAR CANE SHOWING HOLES MADE BY SUGAR-CANE MOTH BORER AND A BORER IN ITS TUNNEL.

The normal tissue is white or yellowish, and the reds and other colors, appearing dark in the illustration, are the results of diseases, especially "red rot," which follow the borer in the cane stalk, causing additional deterioration.

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INTRODUCTION.

For the information of those who are not familiar with sugar cane, especially as grown in the United States, it may be said that the plant is a giant grass known botanically as *Saccharum officinarum*

[1] *Diatraea saccharalis crambidoides* Grote; order Lepidoptera, family Pyralidae.

[2] The writers acknowledge their indebtedness to Dr. W. D. Hunter for his interest and direction, and for the suggestions of Dr. W. Dwight Pierce and Mr. D. L. Van Dine, of the Bureau of Entomology. The tables and charts for life history were made under Dr. Pierce's supervision. The active cooperation of the Louisiana Sugar Experiment Station at Audubon Park, New Orleans, has been of the highest value, credit especially being due to Mr. W. G. Taggart, assistant director, for his suggestions concerning the practical application of methods of control. Mr. S. G. Chiquelin, the former assistant director, cooperated in the work and later made valuable suggestions concerning localities in Cuba where parasites could be obtained. Laboratory space was furnished gratis by the Louisiana Experiment Station, and the writers thank Prof. W. R. Dodson, director, for his many courtesies.

For the technical descriptions of the larva and pupa stages of the insect, the writers thank Mr. Carl Heinrich, of the Bureau of Entomology.

The writers have had the assistance in field and laboratory work of Mr. Ernest R. Barber and others. Valuable cooperation was maintained with Mr. George N. Wolcott, formerly entomologist of the Insular Experiment Station of Porto Rico and later for a short time connected with this investigation. Prof. J. T. Crawley, formerly director, and Prof. P. P. Cardin, entomologist, of the Cuba Experiment Station at Santiago de las Vegas, have been of material assistance in connection with the introduction of the parasitic flies from Cuba. Mr. Edward Foster, of the office of the State entomologist of Louisiana, has assisted with bibliographical and other information.

The drawings were made by Mr. Harry Bradford, of the Bureau of Entomology.

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Linnaeus, that it is grown from cuttings which are laid lengthwise in the rows, that it grows from late spring through the warm months of the year, and that it must be cut before it is damaged seriously by cold weather.

The plant does not produce seeds in Louisiana, though it does in tropical countries and occasionally in southern Florida and the southern tip of Texas. The stalks are cut in the fall, the leafy tops and side leaves are trimmed off and left on the fields, and the stalks are ground in the mill, this being the first step in the manufacture of sugar. The leaves and tops left on the ground usually are called the "trash," but by some "shucks," and by others "flags."

The principal insect injurious to sugar cane in the United States is a moth generally known in the larva stage as "the borer," but it is distinguished from other boring insects of sugar cane by the names "moth borer" and "lesser moth borer." It is a member of the order Lepidoptera, family Pyralidae and subfamily Crambinae, and has the scientific name *Diatraea saccharalis* Fabricius, variety *crambidoides* Grote. It is this insect which is considered in the following pages.

CHARACTER OF INJURY TO SUGAR CANE.

The work of many insects is apparent immediately, even to the untrained observer, but the injury due to the sugar-cane moth borer, familiarly known as the "borer," is the more serious for the reason that it is not noticeable except on close examination. To the casual observer one field of sugar cane is like many others. If the leaves are pulled away from a stalk, however, a few holes may be observed in the rind and perhaps a quantity of sawdustlike material may be seen clinging to the stalk. This is evidence that the moth borer has been at work. If the stalk is split lengthwise, tunnels about an eighth of an inch wide may be found running for several feet, several tunnels sometimes joining in such a way that the plant is greatly weakened and is easily blown down by a high wind.

It is evident that such injury must occasion various forms of loss, in tonnage of cane, pounds of manufactured sugar, etc. The injury is rendered even more serious by the insidious habits of the insect, since the full amount of damage is underestimated by the average planter. Only by walking through the field and examining stalk after stalk can any definite idea of the full amount of injury be obtained.

ESTIMATE OF LOSSES.

Not only are the mature canes injured greatly by the moth borer, but many young plants, especially in the early summer, are killed. (See "Effect on young cane—'dead hearts,'" p. 5.) As many as 100

plants per acre may be destroyed, but so many plants remain in the field that this loss is not great. It should be prevented, however, because it is on these young plants that the borers multiply in sufficient numbers to become a serious menace to larger canes.

Under calculable losses the injury to mature cane alone will be considered. The full amount of injury is shown only by chemical analysis. Infested and uninfested cane from Texas, not affected by red rot, a disease which often follows borer damage, was analyzed, with the following results:

Uninfested.	*Per cent.*	*Infested.*	*Per cent.*
Brix	19.5	Brix	17.55
Sucrose	17.45	Sucrose	15.1
Purity	89.5	Purity	86.0

Dr. William E. Cross, at that time of the Sugar Experiment Station, New Orleans, La., who made the analyses, stated that the loss due to the moth borer was about 20 per cent of the sugar—a greater loss than might be expected from the figures. Mr. John Allbright, chief of the laboratory at Central Chaparra, Cuba, analyzed infested and uninfested cane from a field at that central factory. The results follow:

Uninfested.	*Per cent.*	*Infested.*	*Per cent.*
Brix	21.3	Brix	18.8
Sucrose	19.9	Sucrose	16.85
Purity	93.4	Purity	89.6
Extraction	47.2	Extraction	36.4

Loss in sucrose, 3.3 per cent in cane.
Loss in sucrose, 15.3 per cent in juice.

Messrs. D. L. Van Dine (169)[1] and T. C. Barber (14) have investigated the losses due to the moth borer in considerable detail. Mr. Barber sums up the effect on sugar content in Table I.

TABLE I.—*Analysis of sugar cane (D. 74) to determine effect on sugar content of the borer injury to cane.*

No. of sample.	Nature of sample.	Weight of cane.	Weight of juice.	Per cent of juice.	Loss of juice due to borer.	Total solids in juice.	Loss in total solids due to borer.	Glucose in juice.	Solids not sugar in juice.	Glucose ratio.	Sucrose in juice.	Loss in sucrose due to borer.	Purity.	Loss in purity due to borer.
		Gms.	*Gms.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	Borer-free	9,990	6,108	61.1	.....	17.1	.....	1.6	1.1	11.1	14.4	.....	84.2	.....
2	Medium infested	11,081	6,735	60.8	0.3	16.1	1.0	1.7	1.2	12.9	13.2	1.2	82.0	2.2
3	Heavily infested	8,824	5,190	58.8	2.3	13.7	3.4	2.1	1.8	21.4	9.8	4.6	71.5	12.7

NOTE.—Each sample consisted of 10 canes. Each of the medium-infested canes contained from one to three infested joints, and each of the heavily infested canes five or more infested joints. Analysis made Nov. 12, 1910.

[1] Figures in parentheses refer to entries in the bibliography, pages 63–74.

TABLE I.—*Analysis of sugar cane (D. 74) to determine effect on sugar content of the borer injury to cane*—Continued.

RESULTS OF ABOVE ANALYSIS FIGURED ON A BASIS OF 1 TON OF CANE TO THE SAMPLE.

No. of sample.	Nature of sample.	Weight of cane.	Weight of juice.	Loss of juice per ton due to borer.	Total solids per ton.	Loss in total solids due to borer.	Glucose per ton.	Increase in glucose due to borer.	Solids not sugar per ton.	Increase in solids not sugar due to borer.	Sucrose per ton.	Loss in sucrose due to borer.	Actual loss in sucrose due to borer.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*
1	Borer-free.....	2,000	1,222	.....	208.96	.....	19.55	.....	13.44	.....	175.97	.....	.....
2	Medium infested.....	2,000	1,216	6	195.77	13.19	20.67	1.12	14.59	1.15	160.51	15.46	8.78
3	Heavily infested.....	2,000	1,176	46	161.11	47.85	24.69	5.14	21.17	7.73	115.25	60.72	34.51

He summarizes his results as follows:

The sugar-cane borer damages cane in the field by destroying a considerable percentage of the eyes, thus reducing the stand of plant cane; by stunting the growth of the cane, owing to the physical injury of the stem; by admitting fungous diseases through the wounds in the stem; and is the main cause of injury by the wind, owing to the weakening of the stalk due to the tunnels and burrows. These classes of injury have been appreciated by planters. It now develops that there is another and very important class of injury which has been overlooked. This is the reduction of both the quantity and quality of the juice, which is dealt with specially in this circular. It becomes evident that both the planters and the manufacturers are vitally interested in the work of the sugar-cane borer.

Mr. Van Dine states:

There is a direct loss in sugar and a decided reduction in the purity of the juice of cane infested by the moth stalkborer. This loss in Porto Rico exceeds 670 pounds of sugar per acre of cane in which the infestation was not apparent except upon examination, the yield averaging 41 tons of cane per acre and the stalks being normal and healthy in appearance. The loss increases in direct proportion to the number of joints of the cane stalks infested by the borer. There is more fiber and less juice in borer-infested cane. The actual weight of borer-infested cane is less than that of sound cane, and it is considered that the juice deteriorates more rapidly in infested cane when cane is allowed to stand without being crushed for any length of time after harvest.

In the early bulletin on the moth borer by Dr. W. C. Stubbs and Prof. H. A. Morgan (152) it is found that after the borer became established on Belle Alliance Plantation, in Louisiana, there was "a falling off of 4.98 tons per acre and about 25 pounds of sugar per ton." From the figures given in that bulletin it is calculated that an average yield of 3,455 pounds of sugar per acre accrued on Belle Alliance Plantation before the borer made its appearance, whereas the average yield thereafter was only 2,393 pounds per acre. The loss in sugar from these figures would be 1,061 pounds per acre. At 4.35 cents per pound, which is given as the average price of (white) sugar for three years, the annual money loss per acre due to the moth borer would be $46.15. At the present ruling prices the loss would be correspondingly greater.

"DEAD HEART" CAUSED BY THE SUGAR-CANE MOTH BORER.

Injury of this character results, in a few days, in the death of the young plant.

As calculated from the figures of Mr. T. C. Barber, a similarly high loss is obtained. Mr. Barber estimates a total loss of 1,078 pounds of sucrose per acre where canes are all bored, as they sometimes are. The present writers estimate the loss of 96 test sugar as 1,082.33 pounds per acre. The average price of this grade of sugar on the New Orleans market during the 14 years from 1900 to 1913, inclusive, was approximately 3.87 cents per pound. At this price the money loss where all canes are bored is $41.88 per acre.

During the six-year period from 1912 to 1917, inclusive, in which observations have been made, the average infestation has been about 58 per cent of all the canes in the infested area in Louisiana, which includes the whole sugar belt, except the parishes of Rapides and most of Avoyelles, or about 300,000 acres planted in sugar cane. Fifty-eight per cent of the maximum loss ($41.88) is $24.29 per acre. For 300,000 acres it reaches the high figure of $7,287,000. The losses in southern Florida and the lower Rio Grande Valley, in Texas, would correspond to the acreage. The infestation in Texas is always high.

These figures do not take into consideration the loss due to injury to corn, which must be considerable but is difficult to estimate.

EFFECT ON YOUNG CANE—"DEAD HEARTS."

The first injury of the moth borer to the young sugar-cane plant produces what is known as the "dead heart." This injury is illustrated in Plate I. Among plants from 6 inches to 3 feet in height some usually are to be found in which the outer leaves are a healthy green while the young inner whorl is yellow and dry. The central portion, or "heart," of the plant is dead, and the dying of the rest of the plant is only a matter of days.

This peculiar reaction to injury is rather characteristic of young cane. It is often due to the work of the borer, but it may result from various other causes. Thus some "dead hearts" are caused by a twisted growth of the inner tissues of the plant, the tissues above such a twist ultimately dying. Other "dead hearts" result from accidents of cultivation. A false step of the mule or the plowman may break the brittle inner tissues near the ground, while the outer portion of the plant, being stronger and more elastic, springs erect after the weight is removed. In a short time the heart dies, and an investigation will show that the inner tissues have been broken cleanly and have turned slightly brown at the point of separation.

Insect injury other than that of the moth borer also is responsible for "dead hearts." The work of the sugar-cane beetle (*Ligyrus*) *Euetheola rugiceps* Le Conte, and other insects produces similar injury, the inner portion of the plant being killed before the outer portion.

The "dead hearts" due to the moth borer are caused in the following manner: The adult moths emerge in the spring, when the cane plants are small, and deposit clusters of eggs on the leaves of the young plants. The eggs hatch, and the small larvæ feed here and there on the tender whorls, rolls of holes appearing on the leaves as they expand. Many of the larvæ seem to perish during this period, partly because of their cannibalistic habits. Not more than three larvæ, usually only one, seem to find their way to the interior of a young cane plant. When about half grown a larva crawls down the outside of the stem to a point near or even below the surface of the ground. Gnawing a hole through the outer layer of the stem it works its way to the interior of the plant, cutting the tender inner shoot and forming a "dead heart." The inner shoot does not dry up immediately, so that the larva has some time to work before the injury can be noticed. Tunneling within the plant the insect reaches its largest size, pupates, and finally leaves the plant as an adult moth.

During a year when few plants were killed in this way it was estimated that there were about 10 "dead hearts" per acre. In other years as many as 100 "dead hearts" have been counted per acre.

EFFECT ON MATURE CANE.

While the work of the larvæ on the small plants kills the plants, larger stalks usually do not die. In these the larvæ burrow up and down, sometimes gnawing their way out through the hard rind and reentering at another point. Frequently a mature stalk will harbor two or three larvæ which work in different parts of the cane from the top to the bottom. Three sections of infested cane are illustrated in the frontispiece.

A red coloration, showing dark in the canes illustrated in the frontispiece, usually is observed in the pith along the tunnels. This is the disease "red rot," which is caused by the fungus *Colletotrichum falcatum*. "By far the largest number of stalks become infected [with red rot] through the burrows made by the cane borer," writes Dr. C. W. Edgerton (50), who sums up the injury due to red rot as follows: "First, the loss in stand; second, the killing of the young plants; third, the injury to the leaves; fourth, the loss in per cent of sucrose with a corresponding increase of glucose." "Knowing that a large per cent of the red-rot infection in cane is by means of borer channels," Dr. Edgerton continues, "a greater effort should be made to control the insect."

The spores of other fungi, as well as bacteria,[1] also gain entrance through the borer holes. Cane badly bored is found to be hard and dry, making it more difficult to grind. The growth is checked, and

[1] Prof. Wm. L. Owen (119), formerly bacteriologist of the Sugar Experiment Station at Audubon Park, New Orleans, La., has studied and described a bacterium which he found in the tunnels made by the moth borer in sugar cane. He has given it the name of *Bacillus saccharalis*.

the bored stalks are often blown down by a strong wind. The purity of the juice is lowered, the tonnage decreased, and the sucrose content materially diminished. The eyes are destroyed in many cases, which lessens the value of the infested cane for seed.

EFFECT ON CORN.

The damage of the moth borer[1] to the corn plant has been well described by Mr. George G. Ainslie (2).

> Corn is damaged by these caterpillars in two ways. First, in the early part of the season, while the plants are small, they work in the throat of the young corn, and if the tender growing tip within the protecting leaves is once damaged all chances that the plant will become a normal productive specimen are gone. In many sections of the South this is commonly known as "bud-worm" injury, and though there are several other insects which cause a similar mutilation of the leaf, a very large proportion of the so-called "bud-worm" damage may be charged to this insect. The effect of its work on the leaves of the young corn plants is similar to that resulting from attacks by the corn billbugs (*Sphenophorus* spp.) and is evidenced by the familiar rows of small circular or irregular holes across the blades of the plant.
>
> The other form of serious damage chargeable to this pest occurs later in the season. The larvæ, having then left the leaves and descended to the lower part of the stalk, tunnel in the pith. If the larvæ are at all numerous in the stalk, their burrows so weaken the plant that any unusual strain will lay it low and destroy all chance of its maturing. While frequently ten or more larvæ may live and mature in one plant, it must be remembered that any infestation, however light, will lessen in some degree the vitality of the plant and cause a corresponding loss in the quality and quantity of the harvest.

Not only the stalks of corn, but sometimes the ears are found to contain borers.

The cornstalks, maturing about July or August, when the cane is hardly half grown, become dry and the plants are no longer attractive to the moths for the deposition of eggs. Corn and cane are grown in adjacent fields on sugar plantations, and moths from corn find cane an attractive food plant. Consequently the cane in the middle of the season is attacked not only by moths which have passed their immature stages in cane plants, but by numbers of those which have grown to maturity in corn. It is notable that the number of cane stalks infested by borers increases rapidly from the middle of the growing season until the cane is cut.

HISTORY.

Dr. L. O. Howard (77) wrote an article on the moth borer for the official entomological journal, Insect Life, in 1891, introducing his remarks with an account of the history of the species. We quote him as follows:

[1] Though this account was doubtless written with *Diatraea zeacolella* Dyar in mind, it is correct when applied to the closely allied species *D. saccharalis crambidoides*, which also attacks corn.

The attention of English-speaking people was first called, in a scientific way, to the ravages of a lepidopterous borer in sugar cane by the Rev. Lansdown Guilding in his account of the insects infesting sugar cane, in the Transactions of the Society of Arts, 1828, vol. XLVI, pp. 143–153. He described the insect as *Diatraea sacchari*, and for his paper, which comprehended also an account of the sugar-cane and palm weevils, he was awarded the gold Ceres medal of the society. His studies were made in the Island of St. Vincent in the West Indies, and from its occurrence there at this early date, and from Guilding's statement that it had been long known, there is reason to suppose that the insect may be an indigene of South America or of the West Indies, where the cultivation of sugar cane was first begun in America.

In 1856 a select committee, appointed to investigate the damage caused by the cane borer in Mauritius, reported through W. Bojer, and the insect, which is called in the report *Proceras sacchariphagus*, was treated at some length, and an account was given of its introduction into the island. In the same year Westwood reviewed this report at length in the Gardeners' Chronicle of July 5, gave a woodcut of the insect, and pointed out that it was probably identical with the species described by Guilding at St. Vincent. He also called attention to the fact that the species named many years previously by Fabricius as *Phalaena saccharalis* is probably the same thing. This insect was described by Fabricius (Entomologia systematica, vol. III, part 2, p. 238), from South America, no more definite locality being given. The probabilities are, however, that he refers to Dutch Guiana on account of the early settlement of that country and from the fact that he refers to a figure of the larva by Myhlenfels. He makes the statement that it feeds in sugar-cane, perforating and destroying the stalks and becoming a pest in plantations. He describes the larva as six-footed, of a pale hyaline color, and with the head and eight spots brown. The larval description, however, is drawn from a figure by Myhlenfels, which may have been inaccurate. As Fabricius's work was published in 1793, further evidence is thus afforded that the insect is indigenous to the western hemisphere. This insect still does similar damage in the vicinity of the original source of our information, as is indicated by two articles by Miss Ormerod in the Proceedings of the Entomological Society of London, 1879, XXXIII–XXXVI and XXXVI–XL, and by reports of Mr. Im-Thurm, curator of the British Guiana Museum at Georgetown, published some time previously, but which we have not seen.

In an added note to his Gardeners' Chronicle article, Westwood states that according to information given him by "an intelligent Jamaica cane-grower" the borer was very destructive in Jamaica some 15 years previously (1842), but that its ravages had been greatly checked by allowing the refuse to accumulate on the ground and then firing the whole plantation, the old roots subsequently throwing up more vigorous shoots.

Mr. H. Ling Roth has studied what he believes to be the same species in Queensland (Parasites of the Sugar-Cane, reprinted from the Sugar Cane, March and April, 1885. London, 1885). And in the same year M. A. Delteil (La Canne à Sucre, Paris, 1885) treats of the Mauritius borer and considers it to have been imported from Java, whereas the 1856 commission had considered that it was derived from Ceylon. In 1890 Dr. W. Kruger published in the Berichte der Versuchsstation für Zuckerrohr in West Java, Heft 1, Dresden, 1890, an account of the sugar-cane borers, and figures and describes a species determined as *Diatraea striatalis* Snell., which almost precisely resembles our species, and which he says occurs not only in Java, but also in Borneo, Sumatra, and Singapore. In this same report another similar borer is described by Snellen as *Chilo infuscatellus*.

The West Indian cane borer made its appearance in the sugar-cane plantations of Louisiana at an early date. J. B. Avequin, writing in the Journal de Pharmacie for 1857 (vol. xxxii, pp. 335–337), upon the enemies of the sugar cane in the Antilles and Louisiana, stated that during the two or three preceding years this insect had spread over some of the cane fields of Louisiana, but without having caused up to that time any great damage. He thought that the early frosts towards the end of October or November destroyed great numbers. It appears to have been first noticed in the Parish of St. John Baptist in the year 1855.

Since this time the insect must have been constantly present in the Louisiana cane fields, and has probably been reintroduced from time to time with fresh shipments of seed cane from the West Indies. In the fall of 1878 a few specimens were sent to Dr. Riley by a correspondent of Assumption Parish, Louisiana, and in the spring of 1879 Mr. E. A. Schwarz sent in a bit of cane containing larvæ from the Bahamas. In the spring of 1881, I was sent to Louisiana by Professor Comstock, then entomologist of the Department of Agriculture, to study the sugar-cane beetle (*Ligyrus rugiceps*), and had the opportunity of studying this borer upon the plantation of Dr. J. B. Wilkinson, some 40 miles south of New Orleans on the Mississippi River. Dr. Wilkinson informed me that in 1857 they were very abundant in the Lower Mississippi, and that the crop upon one plantation was utterly destroyed, the cane breaking to pieces as they attempted to cut it.

Concerning the date of the introduction of the moth borer into Louisiana, Stubbs and Morgan (152) conclude that it was introduced long before 1857. "How and when the borer was introduced is not certain," they decide, "but the separate corroborating testimony of Mr. Chamberlain and Mr. Maurin would rather fix the date at 1857, and as canes in large quantities from South America were that year introduced, it is reasonable to conclude that they came from that country as asserted by Mr. Maurin, and not from the West Indies, as Mr. Chamberlain thinks. However, if Col. Pugh and Mr. Bird are accurate in their dates, it was here in quantities before that year." In a footnote to the foregoing these investigators add: "Subsequent investigations have proven that the borer was here in quantities long before the importations of cane described above."

A little-known book by Champomier (32), who issued a series of statistical reports on the sugar industry of Louisiana about the middle of the last century, mentions the "borer worm" in his report for 1856–7. This reference was brought to the attention of the writers by Mr. Edward Foster, of New Orleans.

DISTRIBUTION.

The distribution of the sugar-cane borer (*Diatraea saccharalis crambidoides*) in the United States coincides rather closely with the area devoted on an intensive scale to sugar-cane growing. It is limited to the southern part of Louisiana, the southern tip of Texas, and the southern part of Florida. The borer does not occur in Rapides Parish of Louisiana and is present in only the southeastern part of

Avoyelles Parish. It has not been found in the cane-growing sections of Wharton, Sugarland, and Victoria, Tex.

It is noteworthy that the territory infested in the United States is mostly within the limits of an area known as the Gulf Strip of the Lower Austral Zone.[1] This strip along the coast is indicated in the accompanying map (fig. 1), which shows also the infested regions.

That the insect is found only in three such widely separated places as the southern parts of Texas, Louisiana, and Florida may be explained by the fact that it is a tropical species and probably was brought to these three cane-growing sections independently in shipments of seed cane. Where sugar cane is only an incidental crop it

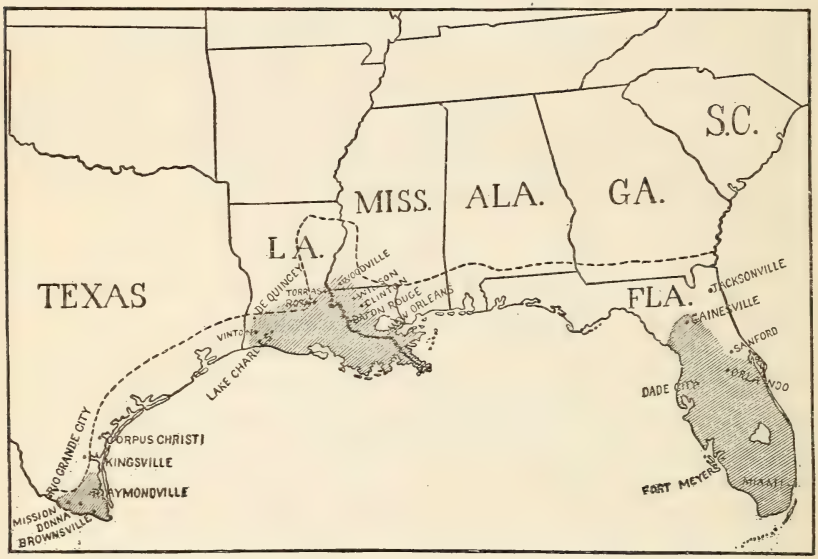


FIG. 1.—Map showing distribution of the sugar-cane moth borer (*Diatraea saccharalis crambidoides*) in the United States. The area below the line of dashes is the "Gulf Strip." Note that the territory infested is practically well within the limits of this biological zone.

does not occur, although a nearly related species attacks corn and very seldom sugar cane in Georgia, northern Florida, North Carolina, South Carolina, and Virginia (75).

SPECIES OF DIATRAEA.

Dr. Harrison G. Dyar (45) records three species of Diatraea in the United States. These are:

Diatraea saccharalis saccharalis Fabricius. French Guiana, Cuba, Trinidad, Peru. Also a female from southern Florida. Probably Santo Domingo.

Diatraea saccharalis crambidoides Grote. Mexico, numerous localities; Gulf States and lower Mississippi Valley.

Diatraea zeacolella Dyar. North Carolina, South Carolina, Virginia.

Diatraea lineolata Walker. Cuba, Trinidad, the Guianas, Venezuela, Costa Rica, Mexico, and southern Arizona.

[1] Merriam, C. Hart. Life Zones and Crop Zones of the United States. U. S. Dept. Agr. Div. Biol. Surv. Bul. 10. 79 p., 1 col. map. 1898.

Dr. Dyar has determined the species from Louisiana as *Diatraea saccharalis crambidoides.*

The authors' observations indicate that *D. zeacolella* occurs in Georgia and northern Florida, as well as in the Carolinas and Virginia. In places in these States where both corn and sugar cane are grown this species has been found to be abundant in corn while rare or absent in adjoining cane fields. Practically, it may be regarded as an enemy of corn exclusively. The larval characters which distinguish *D. zeacolella* from *D. saccharalis crambidoides* have been noted elsewhere by the senior writer (75) and have been further investigated by Mr. Carl Heinrich. (See description of larva, p. 13.)

The southern Arizona species (*D. lineolata*), observed by the authors at Phoenix, Ariz., on sugar cane and Johnson grass, has the distinctive habit of feeding on the leaves of cane until quite large before entering the stalk.

D. saccharalis crambidoides occurs in both corn and sugar cane in the area infested by this variety. It will be noted that the observations of the authors, limiting the variety to southern Louisiana with a small portion of Mississippi, southern Florida, and the lower Rio Grande Valley in Texas, are not at variance with Dr. Dyar's general statement, "Gulf States and lower Mississippi Valley."

The following species of Diatraea are recorded from various parts of the world:

TABLE II.—*Records of species of Diatraea.*

Species.	Distribution.	Authority.
amnemonella Dyar	Castro, Parana, Brazil	Dyar (45)
angustella Dyar	Castro, Parana, Brazil	Dyar (45)
bellifactella Dyar	Sao Paulo and Castro, Parana, Brazil	Dyar (45)
berthellus Schaus	Castro, Parana, Brazil	Dyar (45)
canella Hampson	Grenada; Trinidad; Guiana	Dyar (45)
	British Guiana	Bodkin (17)
continens Dyar	Castro, Parana, Brazil	Dyar (45)
culmicolella Zeller	Colombia	Dyar (45)
grandiosella Dyar	Guadalajara, Mexico	Dyar (45)
instructella Dyar	Popocatepetl Park, Mexico	Dyar (45)
lineolata Walker	Cuba; Trinidad; Guiana; Venezuela; Costa Rica; Mexico; southern Arizona	Dyar (45)
	British Guiana	Bodkin (17)
magnifactella Dyar	Various points in Mexico	Dyar (45)
mauriciella Walker	Mauritius	Hampson (65)
minimifacta Dyar	Trinidad	Dyar (45)
pallidostricta Dyar	Sao Paulo, Brazil	Dyar (45)
pedibarbata Dyar	St. Laurent, Maroni River, French Guiana	Dyar (45)
pedidocta Dyar	Cordoba, Mexico	Dyar (45)
saccharalis Fabricius	British Guiana	Bodkin (17)
	Australia	Jarvis (83)
saccharalis crambidoides Grote	Mexico; United States (Gulf States and lower Mississippi Valley).	Dyar (45)
saccharalis grenadensis Dyar	Grenada	Dyar (45)
saccharalis obliteratellus Zeller	Brazil; Paraguay	Dyar (45)
	Argentina	Rosenfeld and Barber (137)
saccharalis saccharalis Fabricius.	French Guiana; Cuba; Trinidad; Peru; Florida; probably Santo Domingo.	Dyar (45)
saccharalis tabernella Dyar	Canal Zone; Panama; Nicaragua	Dyar (45)
saccariphaga (*mauritella* Walker).	Ceylon; Mauritius	DeCharmoy (52)
strigipennella Dyar	Guiana; Brazil	Dyar (45)
venosata Walker (*striatalis* Snellen).	Java; Borneo	VanDeventer (166) Van der Goot (58), Hampson (65)
zeacolella Dyar	Southeastern United States	Dyar (45)
sp	Philippines	On authority of Muir.

FOOD PLANTS.

Food plants other than sugar cane and corn are broom corn, Kafir corn, milo maize, sorghum (*Sorghum halepense*), Sudan grass (*Andropogon sorghum* var. *sudanensis*), Para grass, vetiver (*Andropogon muricatus*), and feather grass (*Lectochloa mucronata*). Bodkin (20) records rice as a food plant in British Guiana.

A large larva will almost fill the interior of a stalk of grass, but nevertheless will develop successfully.

The number of food plants, some of which grow wild about plantations, makes the species more difficult to control than if it were limited to corn and sugar cane, the larvæ being able to grow to maturity on wild grasses and the adults migrating to the corn and cane fields.

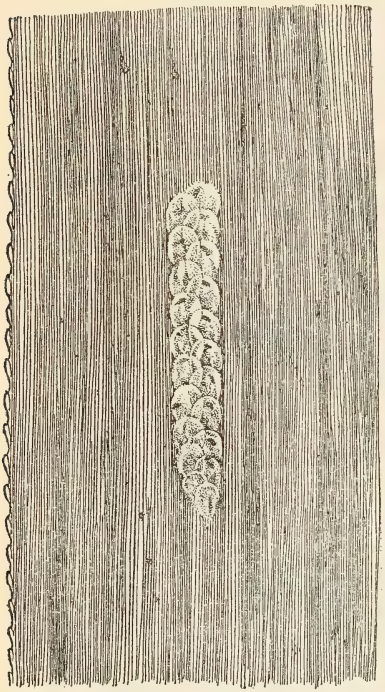


FIG. 2.—Cluster of sugar-cane moth-borer eggs nearly ready to hatch. Much enlarged.

SUMMARY OF LIFE CYCLE.

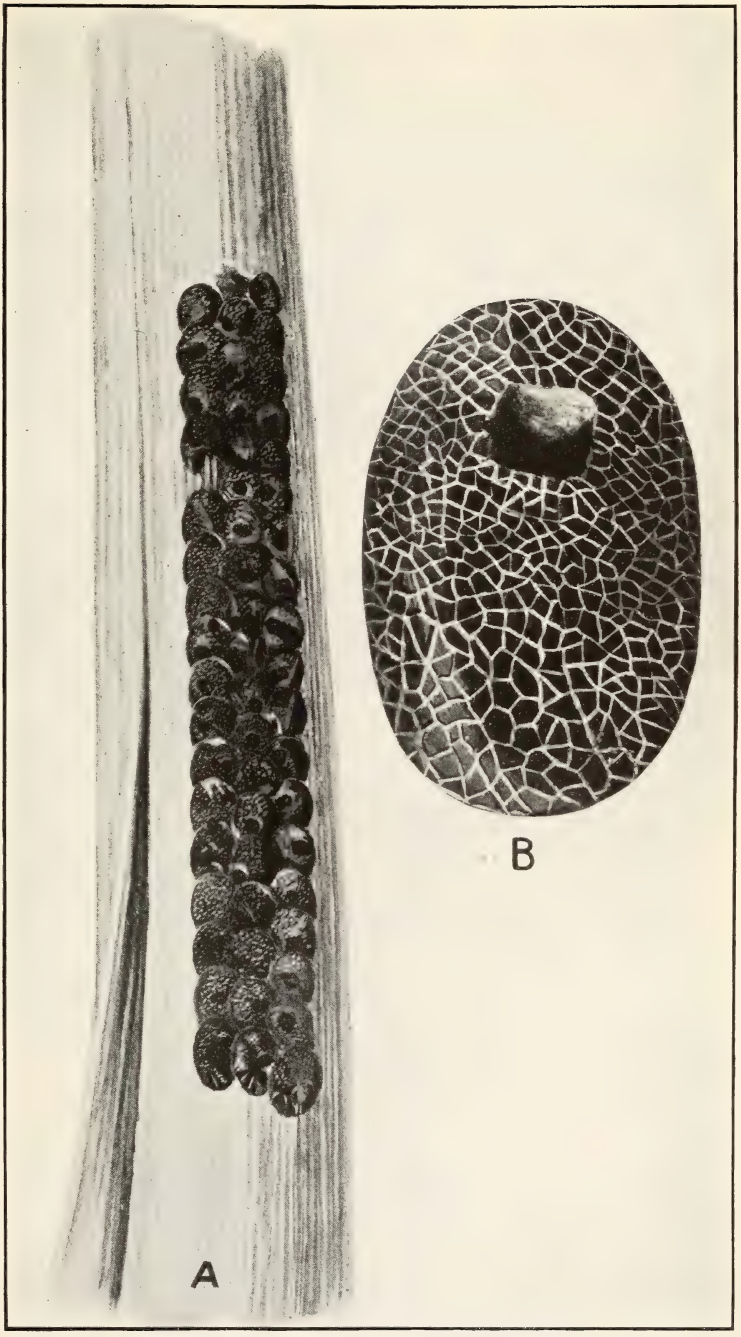
Emerging in the spring, the adult females deposit their eggs on the young plants of sugar cane, corn, etc. These eggs hatch, the young larvæ feeding here and there on the leaves for a short time and then boring into the stalks. After reaching their full development the "borers" pupate and in a few days the moths emerge. Eggs are again deposited, and the life cycle is repeated again and again until winter, during which the larval period is prolonged until spring. The overwintering larvæ then pupate, moths emerge and mate, and the cycle is repeated.

DESCRIPTIONS OF STAGES IN LIFE CYCLE.

THE EGG.

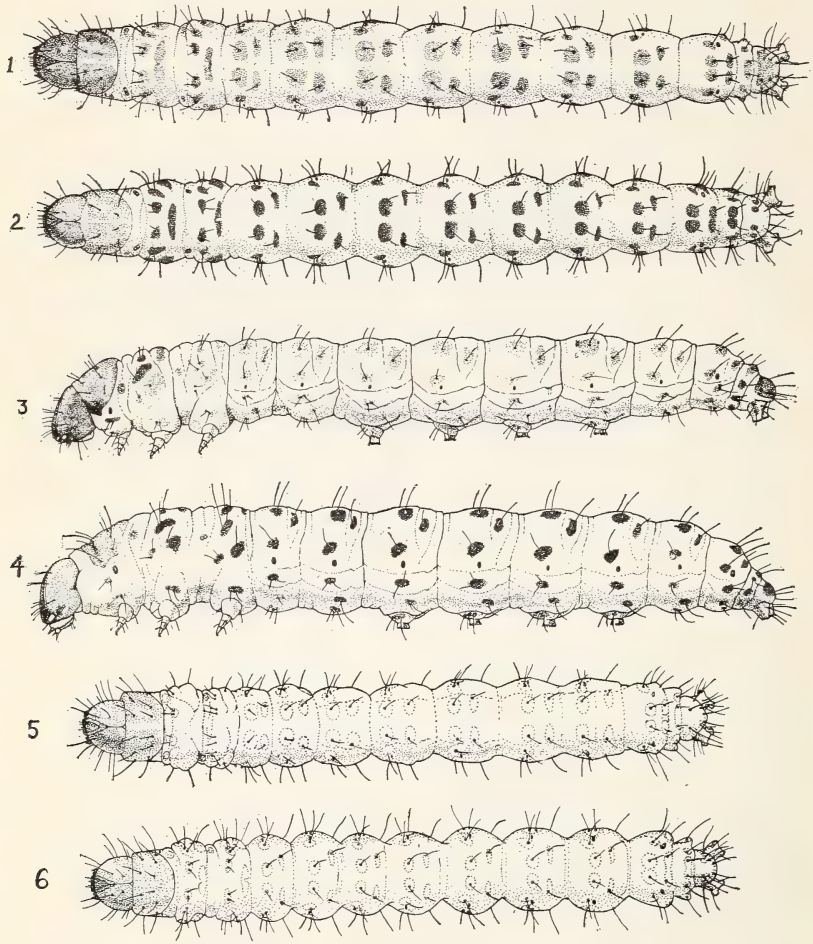
The eggs are round-oval, flattened, about 1.16 mm. long by about 0.75 mm. wide,[1] and are deposited in clusters. Beginning at the top of a cluster they overlap one another (see fig. 2), like scales on a fish. A group or cluster contains from 2 or 3 to 50 or more eggs. The clusters vary in shape as well as in size, a small one often being irregularly round, while the larger ones are much longer than wide—sometimes

[1] One millimeter is about one twenty-fifth of an inch.



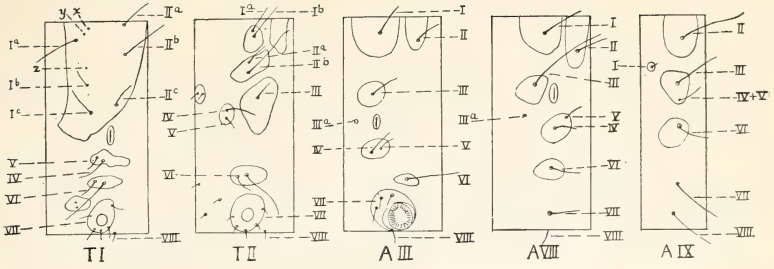
PARASITIZED EGGS OF THE SUGAR-CANE MOTH BORER.

A.—Cluster of moth-borer eggs which have been parasitized. Much enlarged. Note dark appearance and emergence holes of parasites. B.—Individual parasitized egg, showing dark appearance and emergence hole of parasite. Very greatly enlarged.



LARVAE OF THE SUGAR-CANE MOTH BORER AND THE LARGER CORN STALK-BORER.

FIG. 1.—The sugar-cane moth borer (*Diatraea saccharalis crambidoides*): Larva, summer form, dorsal view. FIG. 2.—The larger corn stalk-borer (*D. zeacolella*): Larva, summer form, dorsal view. FIG. 3.—*D. saccharalis crambidoides:* Larva, summer form, side view. FIG. 4.—*D. zeacolella:* Larva, summer form, side view. FIG. 5.—*D. saccharalis crambidoides:* Larva, winter form, dorsal view. FIG. 6.—*D. zeacolella:* Larva, winter form, dorsal view.



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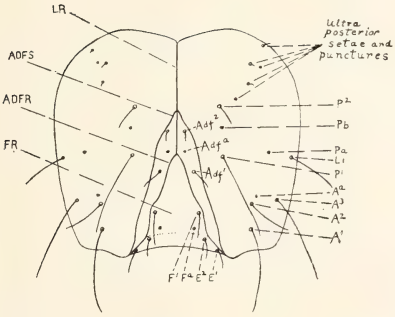

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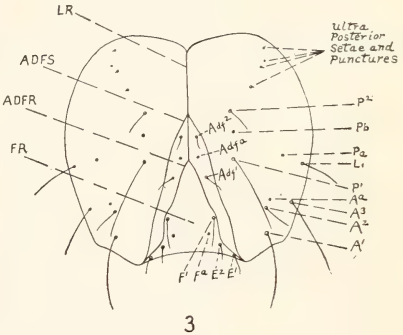

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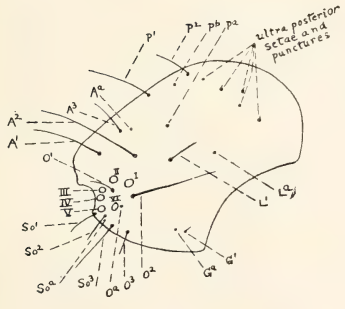

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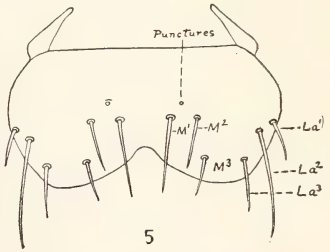

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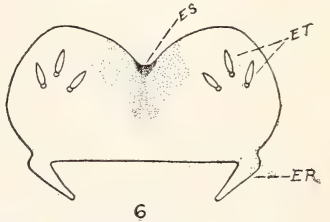

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LARVAL DETAILS OF THE SUGAR-CANE MOTH BORER AND THE LARGER CORN STALK-BORER.

FIG. 1.—The sugar-cane moth borer (*Diatraea saccharalis crambidoides*): Larva, setal maps of body. FIG. 2.—*D. saccharalis crambidoides:* Larval head capsule, dorsal view. FIG. 3.—The larger corn stalk-borer (*D. zeacolella*): Larval head capsule, dorsal view. FIG. 4.—*D. saccharalis crambidoides:* Larval head capsule, lateral view. FIG. 5.—*D. saccharalis crambidoides:* Larval labrum. FIG. 6.—*D. saccharalis crambidoides:* Larval epipharynx.

more than 12 mm. long by 3 mm. wide. They are white at first, but later an orange hue develops. They are lightly sculptured with an irregular network of depressed lines which is visible with a microscope. This sculpturing resembles the "pebble grain" of leather. Just before hatching the black heads of the young larvæ are plainly visible through the eggshell, and the eggs assume a blackish hue.

Eggs may be deposited on either side of a leaf. The fresh ones are very difficult to find, their whiteness blending with the green of the cane or corn leaf. They are securely glued to the leaf surface and in nature are never detached before hatching. Having hatched, the empty shells become translucent white. The appearance of a cluster of eggshells from which the larvæ have emerged has been well likened to a fragment of cast snake skin.

When parasitized the eggs gradually turn jet black and remain so even with the emergence of the parasites. Because of their color, parasitized eggs are much more easily detected in the field than are the normal eggs. The holes made by the parasites in emerging are readily discernible. (Pl. II.)

THE LARVA.

The larva, which is the form of the insect most familiar to sugar planters, is about 1 inch long by one-eighth inch wide. In this form the insect commits its ravages. The head is brown and the body white with brown spots. This is the summer coloration of the larva, but in the winter it loses its spots and the body assumes a uniform dirty white.

Technical descriptions of both the winter and summer forms (full-fed larvæ) have been published elsewhere by the senior writer (75), and they have now been corrected by Mr. Carl Heinrich to conform to the latest knowledge of lepidopterous larval characters. His descriptions are given below.

General Characters.

No secondary hairs. Legs and prolegs normal. Crochets triordinal and in a complete circle. No anal fork. Prothoracic shield broad, divided. A narrow pigmented shield on mesothorax, caudad of setæ I*a* and I*b*, bearing no setæ. Spiracles elongate oval; prothoracic spiracle twice the size of those on abdominal segments 1 to 7; that on segment 8 slightly larger than prothoracic and slightly dorsad of other abdominal spiracles. (Pl. III, figs. 1, 3, 5.)

Body setæ (Pl. IV, fig. 1) moderately long; tubercles prominent, broadly chitinized; IV and V on abdominal segments 1 to 8 under the spiracle and approximate; prespiracular shield of prothorax narrow, horizontally elongate, bearing only two setæ (IV and V) situated ventro-cephalad of the spiracle, III of prothorax absent; group VI bisetose on prothorax, mesothorax, and metathorax;[1] IV and V united on abdominal segment 9 and approximate to III;

[1] This is the Pi group of Fracker which he erroneously describes as unisetose in the Crambinae. See Fracker, S. B. The classification of lepidopterous larvæ. Illinois Biological Monographs, v. 2, No. 1. 169 p., 10 pl. 1915. (See p. 87, 91.)

III above the spiracle on abdominal segments 1 to 7, before the spiracle on abdominal segment 8; III*a* rudimentary or indistinguishable, before the spiracle on abdominal segments 1 to 7, ventro-cephalad of the spiracle on abdominal segment 8; group VII trisetose on abdominal segments 3 to 7, unisetose on abdominal segments 8 and 9; abdominal segment 9 bearing six prominent setæ in a nearly vertical line, I rudimentary or absent, when distinguishable it is latero-cephalad of II and equidistant from II and III; on the other abdominal segments II is slightly shorter than, and latero-caudad of I; setæ and punctures on prothoracic shield as follows: I*a*, *b*, *c* behind the frontal margin of the shield, distance separating I*b* and I*c* equal to that between II*a* and II*b*, II*a* dorso-caudad of I*a*, puncture *z* slightly lower than the level of II*b*, punctures *x* and *y* dorso-caudad of I*a*, distance between I*c* and II*c* slightly less than that between I*b* and I*c*.

Head capsule (Pl. IV, figs. 2, 4) spherical, slightly trapezoidal or broadly oval (nearly square) in outline viewed from above, as wide or a trifle wider than long; greatest width back of middle of head; incision of dorsal hind margin slight; distance between dorsal extremities of hind margin less than one-half the width of the head. Frons (FR) a trifle longer than wide, not quite reaching to middle of head; adfrontal ridges (ADFR) parallel from lower limit of epistomal area to point of juncture of tentorial arms, thence converging in slightly curved lines to the longitudinal ridge (LR); longitudinal ridge slightly longer than frons: adfrontal sutures (ADFS) meeting longitudinal ridge slightly behind middle of head. Projection of dorsal margin over ventral less than one-half the diameter of the head.

Ocelli six (Pl. IV, fig. 4); I larger and III smaller than the others; III and IV closer together than any of the others.

Epistoma (Pl. IV, figs. 2, 4) with the normal setæ (E^1, E^2).

Frontal punctures (Pl. IV, figs. 2, 4) (F^a) well separated; distance between punctures considerably greater than distance from puncture (F^a) to seta (F^1); distance from frontal seta (F^1) to seta Adf^1 about equal to distance separating adfrontal setæ (Adf^1 and Adf^2); Adf^2 well behind beginning of longitudinal ridge; puncture Adf^a equidistant from Adf^1 and Adf^2 and approximate to beginning of longitudinal ridge.

Epicranium (Pl. IV, figs. 2, 4) with the normal number of primary setæ and punctures and with three ultraposterior setæ and one or two ultraposterior punctures. Anterior setæ (A^1, A^2, A^3) in a right angle; A^2 equidistant from A^1 and A^3; anterior puncture posterior to A^2. Posterior setæ (P^1, P^2) and puncture (P^b) of posterior group lying parallel with longitudinal ridge; P^1 nearly on a level with beginning of longitudinal ridge; P^2 on, or nearly on a level with place of juncture of adfrontal sutures with longitudinal ridge; P^b between P^1 and P^2; P^a slightly nearer to L^1 than to any other seta, lying between L^1 and P^1. Lateral seta (L^1) remote from A^3, on a level with P^1; lateral puncture (L^a) directly posterior to the seta, remote. Ocellar setæ (O^1, O^2, O^3) well separated; O^1 equidistant from and ventrad of ocelli II and III; O^2 directly ventrad of and approximate to ocellus I; O^3 remote from and ventrad of O^2, nearer to SO^3 than to O^2; puncture O^a closely approximate to ocellus VI. Subocellar setæ (SO^1, SO^2, SO^3) triangularly placed; puncture SO^a equidistant from setæ SO^2 and SO^3. Genal puncture (G^a) anterior to seta (G^1).

Labrum (Pl. IV, fig. 5) with median incision moderately concave; setæ M^1, M^2, and M^3 triangularly placed; M^1 and M^2 nearly on a line with La^1; La^1 and La^2 closely approximate; M^3 and La^3 on a line; distance separating M^3 and La^3 about equal to that between M^2 and M^3; puncture equidistant from and slightly back of M^1 and M^2.

Epipharyngeal shield (Pl. IV, fig. 6) (ES) not sharply defined, merging in a broadly chitinized area on the central forward part of the labrum. *Epipharyngeal setæ* (ET) triangularly grouped, well behind anterior margin of epipharynx, moderately long, narrow, equidistant. *Epipharyngeal rods* (ER) indicated only by their prominent posterior projections.

Maxillulæ normal.

SPECIFIC DESCRIPTION.

Summer form (Pl. III, figs. 1, 3; Pl. IV, fig. 2): Head slightly trapezoidal in outline viewed from above; widest at the level of the posterior seta P^2; lateral and frontal margins nearly straight; posterior region broad, not constricted; ultraposterior setæ of epicranium forming a very obtuse angle, with the apex of the angle pointed to the longitudinal ridge (LR); color rich brown, varying to black at mouth parts and to orange on dorsal aspect. Prothoracic plate pale brown, tinged with black ventrally. Body white. Tubercles light brown or paler. Abdominal tubercles II oval and about twice as far apart as tubercles I. Setæ yellow to brown. Imaginary lines connecting setæ I and II of abdominal segments 3, 4, and 5 (text fig. 3, *a*) on each side, if prolonged, form angles averaging 30.2 degrees. Tubercle I on ninth abdominal segment discernible. Spiracles dark brown. Average length (10 specimens) 25.6 mm.

Winter form (Pl. III, fig. 5): Differs from the summer form in the following characters: Color yellow to rich brown, varying to black at mouth parts and to yellow on dorsal aspect. Prothoracic plate yellow. Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles dark brown, distinct and sharply contrasting with rest of body. Average length (10 specimens) 22.4 mm.

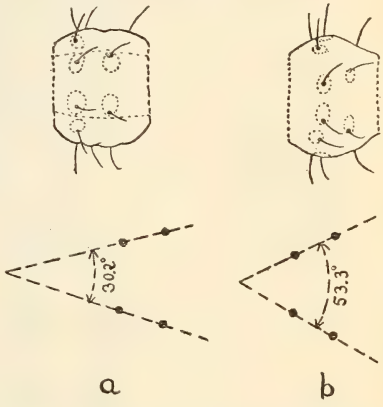


FIG. 3.—*a*, Fourth abdominal segment, dorsal view, of larva of sugar-cane moth borer (*Diatraea saccharalis crambidoides*), and diagram of angle formed by imaginary line through bases of setæ; b, same for larger corn stalk-borer (*Diatraea zeacolella*).

As the nearly related species *Diatraea zeacolella* is liable to confusion with *D. saccharalis crambidoides*, Mr. Heinrich has furnished the following descriptions:

SPECIFIC DESCRIPTION OF LARVA OF DIATRAEA ZEACOLELLA.

Summer form (Pl. III, figs. 2, 4): Head broadly oval, widest at the level of posterior puncture P^b; the lateral and frontal margins slightly but evenly rounded; posterior region slightly constricted, narrower than middle of head; ultraposterior setæ forming a very obtuse angle, with the apex of the angle pointed to the lateral margin. (Pl. IV, fig. 3.) Color yellow, varying to black at mouth parts. Prothoracic plate yellow. Body white. Tubercles dark brown, contrasting sharply with ground color of body. Abdominal tubercles II narrowed and about four times as far apart as tubercles I. Setæ yellow to brown. Imaginary lines connecting setæ I and II of abdominal segments 3, 4, and 5 (text fig. 3, *b*) on each side, if prolonged, form angles averaging 53.3 degrees. Tubercle I of ninth segment not discernible. Spiracles black. Average length (3 specimens) 25.2 mm.

Winter form (Pl. III, fig. 6): Differs from summer form in the following characters: Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles black, very distinct, and sharply contrasting with rest of body. Average length (4 specimens) 24.5 mm.

THE PUPA.

On molting for the last time the larva enters the pupa stage, the quiescent period of the insect. The pupa (fig. 4) at first is white, but soon changes to a dark brown. It is cylindrical in form and bears little resemblance to either the larva or the moth. The following technical description has been written by Mr. Carl Heinrich:

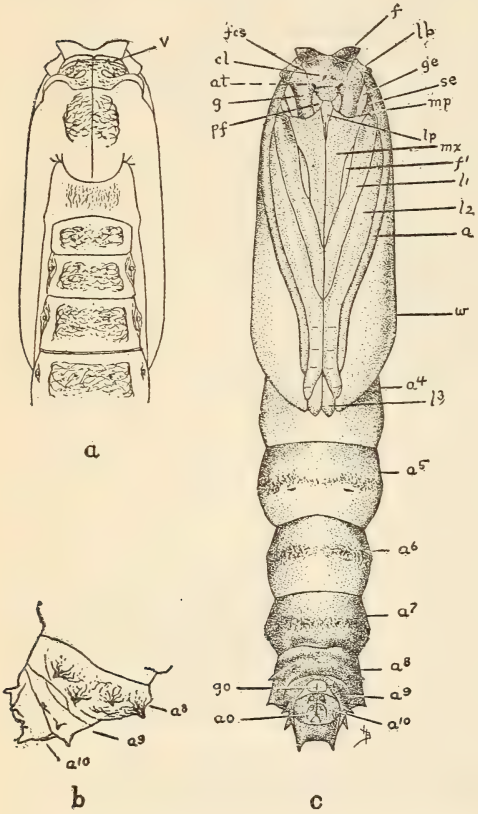


FIG. 4.—Pupa of sugar-cane moth borer: *a*, Dorsal view of anterior portions; *b*, lateral view of anal segments; *c*, ventral view of entire pupa.

GENERAL CHARACTERS.

Elongate; slender, pilifers well developed; maxillary palpi present; prothoracic and mesothoracic legs not extending cephalad between sculptured eyepiece and antenna; sculptured and glazed eyes, labrum, frontoclypeal suture, and invaginations for anterior arms of tentorium clearly indicated; front extended upward into two hornlike projections; maxillæ prominent, only half the length of the wings; wings extending to midventer of fourth abdominal segment; mesothoracic legs not extending to end of wings; metathoracic legs extending to, or a trifle beyond, tips of wings; femora of prothoracic legs clearly indicated; antennæ not reaching tips of wings; body roughened but without hooks or prominent setæ; cremaster absent; posterior end broad; tubercles of the eighth, ninth, and tenth segments developed into stout, sharp, thornlike projections; dorsum of prothorax, mesothorax and metathorax and the first nine abdominal segments rugosely scobinate; on segments 5, 6, 7, and 8 of the abdomen the scobinations form a median band encircling each segment; a deep furrow on dorsum separating ninth and tenth abdominal segments; genital opening single and slitlike in both sexes; anal opening a slit terminating in two short lines (⁞); spiracles elongate, oval, moderate, easily distinguishable.

SPECIFIC DESCRIPTION.

Sixteen to 20 mm. long; yellow or yellowish brown, darkest at caudal and cephalic ends; the front, clypeus, scobinate areas, and enlarged abdominal tuber-

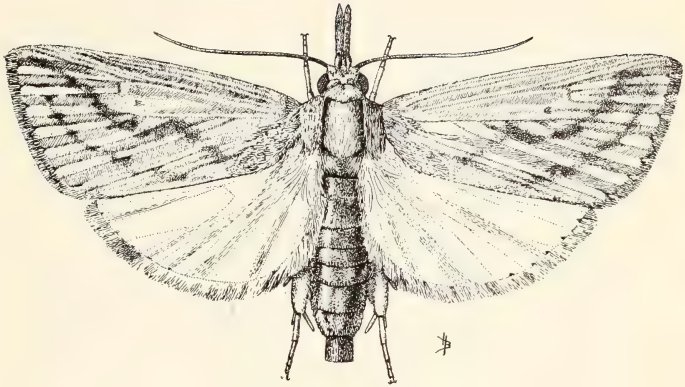


FIG. 1.—ADULT MALE.

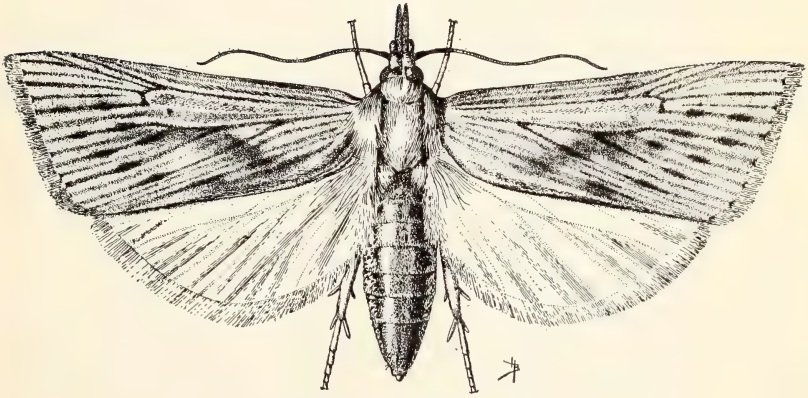


FIG. 2.—ADULT FEMALE.

THE SUGAR-CANE MOTH BORER (DIATRAEA SACCHARALIS CRAMBIDOIDES).

MATURE STALKS OF SUGAR CANE, SHOWING EMERGENCE HOLES OF MOTH BORER.

A.—Variety "Louisiana Purple." B.—Variety "D 74."

cles dark brown, in some specimens almost black; thornlike tubercles of abdominal segments 8, 9, and 10 stout and very prominent.

THE ADULT.

The adult (fig. 5; Pl. V) is a straw-colored moth, the forewings marked with darker lines. It varies in size, average specimens measuring about an inch across the wings.

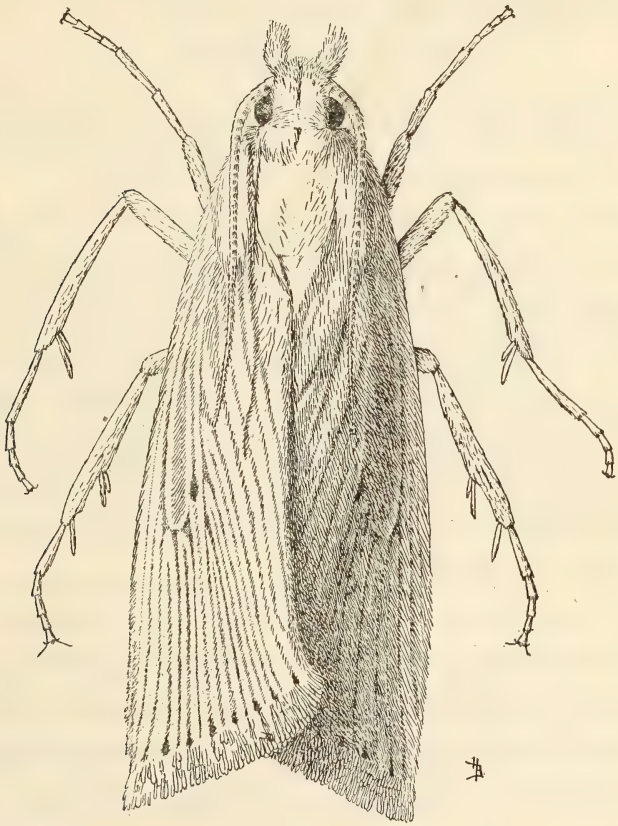


FIG. 5.—The sugar-cane moth borer: Adult with wings folded.

In his article, "The American Species of Diatraea Guilding," Dr. Harrison G. Dyar (45) describes the moth as follows:

Diatraea saccharalis Fabricius.

This species is divisible into a number of well-marked geographical forms. Two of them occur in the United States. The typical *saccharalis* reaches us by the way of the West Indies and occurs in Florida. The race *crambidoides* Grote comes from Mexico and occurs in the Gulf States. . . .

Diatraea saccharalis crambidoides Grote.

Chilo crambidoides Grote, Can. Ent., XII, 15, 1880.

? Crambus lincosellus Walker, Cat. Brit. Mus., XXVII, 162, 1863.

In this form the front is roundedly prominent, slightly projecting above the eyes, but without cone or tubercle. The male has the hind wings dusky, those

of the female are white. The wings are narrow, outer margin oblique, apex pointed. The male is brownish ochre in color, the female straw yellow; the two rows of brown dots are distinct in both sexes.

Range: Mexico, numerous localities, Gulf States, and lower Mississippi Valley.

Grote's *crambidoides* was described from Kansas, so there can hardly be any doubt of the application of the name. Walker's *lineosellus* was described from Honduras, whence I have no material. If the names shall be found to refer to the same form, Walker's name would have priority.

INSECTARY METHODS.

Experiments with the sugar-cane moth borer were conducted at New Orleans in a room open on all sides, wire screen taking the place of walls and allowing free access of air and moisture.

Cylindrical cages of wire screen were used for the adults. Shortly after emergence the moths were transferred to these cages, which were made by sewing together with wire the edges of pieces of ordinary window screen, these pieces being cut of such a size as to form cages about 7 inches high by 6 inches wide. Some of the horizontal strands of wire were pulled off the top and pieces of cheesecloth were stretched across so that the exposed ends of the vertical wires would extend through the cloth, thus holding it firmly in place. These cages were placed over saucers of damp sand, and the adults were supplied with young cane or corn leaves in tubes of water for oviposition. The females laid eggs readily on the leaves and also on the sand and the sides and tops of the cages.

The leaves with the masses of eggs were then transferred to specimen jars about $3\frac{1}{2}$ inches wide by 12 inches high, covered with cheesecloth. On hatching, fresh food was supplied as needed, and the young larvæ were allowed to remain until after the first molt, when they were transferred to individual tubes. These were about half an inch in diameter by 7 inches long, made by breaking ordinary glass tubing. One larva, with pieces of fresh stalks of cane or other food plants, was placed in each tube, the ends of which were firmly plugged with cotton batting. A number of tubes were placed in a cigar box, the dark interior of which was somewhat similar in degree of illumination to the interior of a cane plant. The actions of the larvæ were easily observable through the glass. The tubes were very easily cleaned by forcing a wad of cotton through them from end to end with a rounded stick or plunger.

The pupæ were placed on damp sand under ordinary drinking glasses.

Temperature and humidity apparatus used in the experiments were maximum and minimum thermometers, sling psychrometer, and recording hygrothermograph.

LIFE HISTORY.

MOTH.

EMERGENCE.

The moth, or adult, emerges from the pupa, which is in a stalk of cane, corn, or other food plant, easily breaking the threads of silk spun by the larva in the tunnel, and forcing its way through the side of the stalk by breaking a thin membrane of plant tissue left by the larva for its ready emergence when it should reach the adult stage. The emergence holes are shown in Plate VI. On emerging the wings are still close to the body, and the moth rests on a convenient leaf or stalk for some time to allow them to expand.

PROTECTIVE HABITS.

An adult of the moth borer is very seldom seen, even in the fields of an infested plantation. The moths fly at night and hide among the corn or cane leaves in the daytime, moving only if disturbed. As they are small and of a light-brown color, similar to the dead leaves of cane or corn, they are not readily observed at any time.

The eggs, which are deposited on the leaves of food plants, blend with the leaves and can be found only with difficulty. The entire pupal period, with most of the larval period, is spent in the burrows formed in the stalks, and in this protected situation the borers are safe from birds and most predacious insects.

FERTILIZATION.

The mating of the moths undoubtedly occurs at night, but it has not been observed by the writers. Pairs of moths were placed in small cages made of wire screen and cheesecloth and examined during the evening and at intervals through the night, but the moths were never found in copula. Examinations were begun as early in the evening as 5.40 p. m.,[1] and were continued on one night at short intervals until 11.20 p. m., with three more observations at 2.50, 3.05, and 5.45 a. m. On another night examinations were made at 5.40, 6.40, and 9 p. m., at 11.45 p. m. to 12.30 a. m. (continuously), at 1.35 to 1.50 a. m. (continuously), and at 2.15, 3.50, and 7.15 a. m.

OVIPOSITION.

In ovipositing the female stands on a leaf with the head upward. She feels about on the leaf with the extended ovipositor and then deposits one egg, pressing it down and flattening it against the leaf with the end of her ovipositor, the egg adhering to the leaf like a tiny fish scale. Then she moves the ovipositor down or to one side,

[1]All references to clock time refer to Standard Time.

and another egg is deposited, part of it extending over a portion of the surface of the first egg. More eggs are deposited in the same way, the female gradually moving downward and backward, so that she stands over the slowly enlarging cluster. As the eggs overlap, one being deposited partly over the other, the completed cluster more than ever resembles a group of fish scales (see Pl. II).

In this action the moth is very quiet, her wings folded, antennæ back, and legs apart. She keeps the tip of her ovipositor pressed against the leaf continuously, making it difficult for an observer to ascertain the exact time any one egg is deposited. During the action she raises the body "on tiptoe," relaxing and resting against the leaf at intervals. One cluster of 6 eggs was formed in 16½ minutes, and another moth laid 34 eggs in 8 minutes.

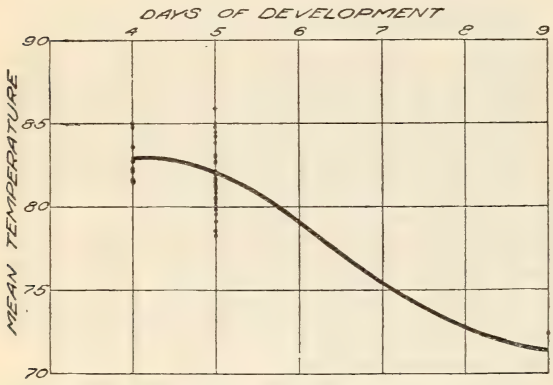


FIG. 6.—Diagram showing relationship of mean temperature to length of egg period of the sugar-cane moth borer, and indicating line of calculated means. The dots represent period means of individuals.

Oviposition is begun at dusk and continues throughout the night, the female flying and walking occasionally. Many clusters of different numbers of eggs may be formed in the same night. Individuals deposit eggs during one, two, three, or four nights, never longer. Oviposition is extended over several nights in cooler weather. Males in the same cage with egg-laying females are indifferent, paying no attention to their mates.

EGG.

DURATION OF THE EGG STAGE.

The duration of the egg stage has been found to be from 4 to 9 days, depending on the temperature, with the average for the year a trifle over 5 days. These results have been obtained from experiments in the insectary, but it is probable that greater variations between the minimum and the maximum periods occur in the field. The period of incubation has been lengthened to 12 days by placing the eggs in an ice box and it is likely that they will stand even greater retardation without being killed. The temperature in the ice box was not very low and eggs laid in the early spring or late fall would probably require as long to hatch. The average length

of the egg stage at the prevailing temperatures during the different months is shown in Table III and is graphically illustrated in figure 6.

TABLE III.—*Relationship of mean temperature to the developmental period of the sugar-cane moth borer in the egg stage.*

Period.	Average mean temperature.	Number of records.	Period.	Average mean temperature.	Number of records.
Days.	° *F.*		*Days.*	° *F.*	
4	82.8	10	7	75.2	1
5	81.7	41	8	72.1	1
6	78.9	7	9	72.4	1

DEVELOPMENT.

When the eggs are first deposited they are creamy white, and in a field of cane are practically invisible against the light green of the cane leaves. They gradually darken until they are reddish brown, with the eyes of the embryo showing through as two small black spots. Later the head turns black and the eyes can not be distinguished, but the segments of the larva are discernible. The head seems to fill the whole egg cavity and gives to the egg mass a bluish-black cast. Just before hatching the larva can be seen moving within the eggshell.

HATCHING.

Hatching usually occurs in the early morning during the summer, and later in the day in cooler weather. Observations indicate that all eggs in a given cluster hatch within a few hours. The larva emerges from the egg by rupturing the upper surface, leaving it torn and ragged but without altering the arrangement or position of the egg in the cluster. The empty eggshells are papery and almost transparent, but they show a slight marking under the microscope. The cluster of eggshells adheres to the leaves for some time before being washed away by rains, and is more conspicuous at this period than it is before hatching.

While no definite record has been maintained of the percentage of eggs which hatch, it is only occasionally that one or two in a cluster from a fertilized female fail to produce larvæ. Eggs from unfertilized females do not hatch.

LARVA.

FOOD HABITS.

The larvæ are active from the time of hatching and almost immediately begin their search for food. Those from a single group of eggs congregate in the terminal buds of two or three plants in the immediate vicinity of the place where hatched and begin feeding

at once. They are active and can move about and lower themselves with silken threads, but they do not seem to travel far from the place of hatching. They go well down into the "bud" or whorl of the plants, where they are protected from bright light and from possible enemies, and they suffer no harm if, as is frequently the case, the bud is full of water. Young larvæ have often been observed to crawl down into a bud which was completely submerged and feed for several hours under water without any apparent discomfort. Some of them at first eat only the epidermis from one side of the leaf, causing a yellowish blotch, but a little later they burrow through the leaves while these are still unrolled. As one leaf is thus pierced in a number of places at once a row of holes arranged horizontally will be seen when it expands. Very often the larvæ burrow into the midrib, following a zigzag course for several inches along its length. They can be seen very plainly by holding the infested leaves up to the light. The larvæ usually leave the buds or the midribs after the first molt and crawl down between the leaf sheaths and the stalk, some of them entering the stalk immediately and others feeding for a day or two, or until after the second molt. It seems that the larvæ feed longer outside the stalks on old cane than on young plants. The species of Diatraea which occurs at Phoenix, Ariz. (*D. lineolata*), has been observed to spend its entire larval and pupal periods in the midrib.

The larvæ feed either up or down from the place of entrance, but usually upward, producing a winding burrow or tunnel a foot or more up the stalk. The burrows may be branched or two or more may unite, forming a network of tunnels in a badly infested stalk. The tunnels are quite small at first, but they are enlarged as the larvæ increase in size until they are one-eighth to one-fourth inch in diameter, allowing the larvæ to move about and turn round with freedom. The frass is packed loosely behind the larvæ, seldom completely closing the passages. The burrows usually become infested with the red-rot fungus within a short time, causing the surrounding tissue to turn red, the discoloration often extending for several inches beyond the burrow (see frontispiece).

CANNIBALISM.

When larvæ are confined in cages in the insectary they are cannibalistic, especially in the smaller stages. If 200 or 300 newly hatched larvæ are left together they will be reduced to 40 or 50 within two or three days. The smaller ones are usually eaten by the larger when larvæ of different stages are confined together, though full-grown ones also are attacked. It seems that the larvæ usually are attacked when they are weak or inactive, especially just before or after molt-

ing. Three or four larvæ often are found living in the same stalk of cane, but in these cases they are more or less separated by their burrows, and it is not likely that large larvæ are eaten by others under field conditions, where they have freedom of action, whereas the habit of small larvæ of congregating in the terminal buds of the plants is very conducive to cannibalism, and many doubtless are destroyed by their companions.

GROWTH.

The rate of growth is dependent upon many external conditions, the temperature and kind of food being the most important factors,

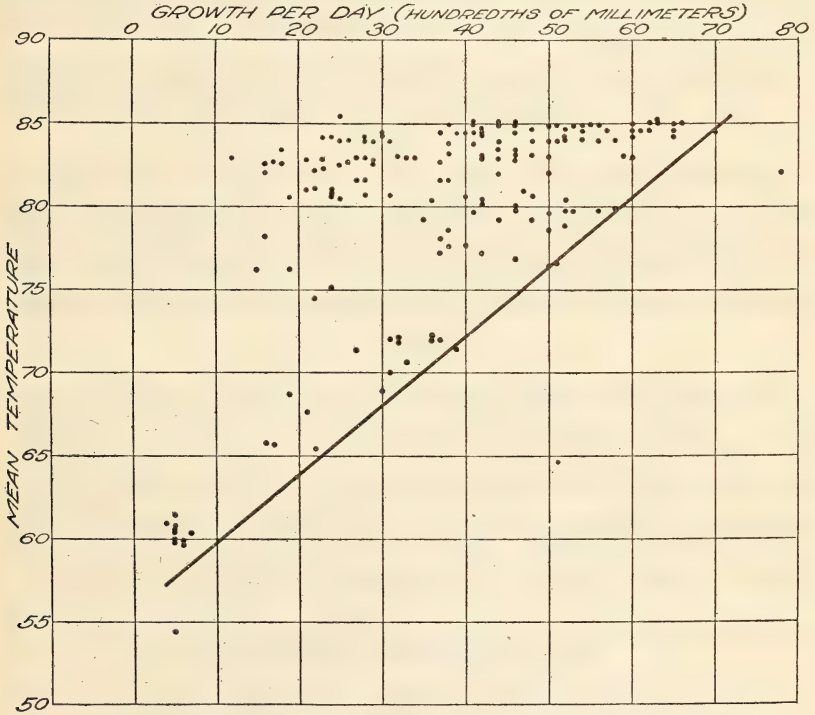


FIG. 7.—Diagram showing relationship of mean temperature to larval growth of the sugar-cane moth borer per day in hundredths of millimeters, showing line of maximum growth of normal individuals. The dots represent growth of individuals in hundredths of millimeters.

but larvæ feeding under similar conditions show a great variation in the rate of development and in the length of the larval period, as is shown by figure 7. Under favorable conditions the rate of increase in body length is about 0.75 mm. per day, but it is often much less. Larvæ are from 1.5 to 2 mm. long when hatched and from 25 to 30 mm. long when fully grown.

MOLTS.

Before molting the larvæ stop feeding for a few hours or sometimes longer and appear stiff and helpless. The skin then ruptures

just back of the head, and by a series of contractions and contortions it is worked back over the body. Sometimes the head capsule is cast before the skin and at other times not until afterwards, but usually it is cast during the process of molting. The capsule is worked loose by the movements of the body and is deposited at one side.

The freshly molted larvæ are white and almost colorless, or show faintly purplish markings running the length of the body. The head is white and soft when first molted, but it turns mahogany brown in a few hours and the markings deepen. Rosenfeld and Barber (137) say that the color of the protective fluid secreted by the larvæ is determined by the color of the head and that the fluid is white in freshly molted larvæ.

The whole process of ecdysis requires about 15 minutes. The larvæ then turn, eat the discarded skin, and recommence feeding on the cane.

Ordinarily there are 5 molts, but sometimes there are only 4 in rapidly-developing larvæ. More than 5 are fairly common, as many as 14 having been observed in hibernating larvæ. When the larval period is prolonged by low temperature or other conditions, the larvæ continue molting, with little or no increase, or even a decrease, in size.

INSTARS.

The period from hatching until the first molt is called the first instar. Between the first and second molts the period is known as the second instar, and so on until the larva reaches the pupa stage. The last instar is the period between the last larval molt and the beginning of the pupal period. The number of instars has been found to be from 3 to 10, with 5 as the most common number. The number in relation to mean temperature is shown in Table IV.

TABLE IV.—*Relationship of mean temperature to the number of instars of the larva of the sugar-cane moth borer.*

Number of instars.	Average mean temperature.	Number of records.	Number of instars.	Average mean temperature.	Number of records.
	° *F.*			° *F.*	
3	74.8	14	7	78.9	18
4	80.3	65	8	69.8	11
5	81.1	102	9	68.8	8
6	82.2	50	10	65.5	4

DURATION OF LARVAL PERIOD.

The larval period is the most variable of all the stages in the life history of this insect, as it is this stage which is prolonged by hibernation or adverse conditions. The first molt takes place from 3 to 6 days after hatching, when the larvæ are from 2 to 4 mm. long. From 4 to 8 days are spent in the second instar, and during this

period the larvæ attain a length of from 6 to 9 mm. The third instar is somewhat longer and requires from 6 to 9 days, the larvæ reaching 10 to 15 mm. in length, while the fourth instar lasts from 4 to 6 days, at the end of which the larvæ are 15 to 20 mm. long. From 3 to 6 days are spent in the fifth instar, and the larvæ attain a length of from 20 to 30 mm.

The usual time required for the larva stage under favorable conditions is from 25 to 30 days in summer and from 30 to 35 days in the cooler weather, but it may be much longer. Larvæ from the same mass of eggs and reared under exactly the same conditions vary a great deal, and some of them require two or three times as long as others to pupate. Under the most favorable conditions the larval period has been as short as 18 days, and has varied from this to 276 days for hibernating larvæ. The larvæ are very adaptable in this

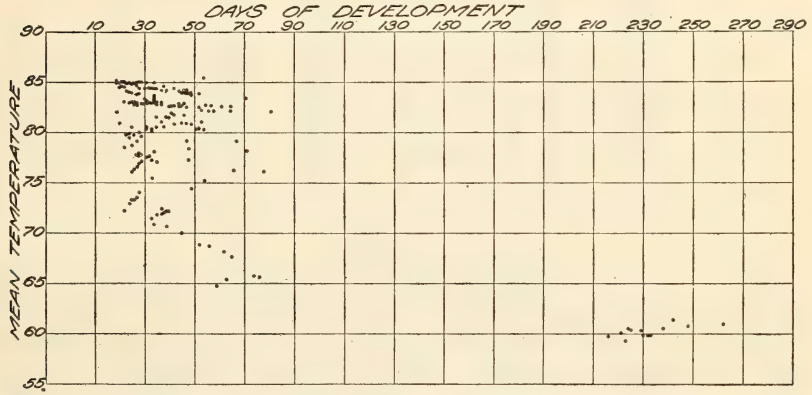


FIG. 8.—Diagram showing relationship of mean temperature to length of larval period of the sugar-cane moth borer. The dots represent period means of individuals.

way and can pass over periods of cold or food shortage without serious inconvenience. Typical life histories at different seasons of the year are shown in Table V and figure 8.

TABLE V.—*Relationship of mean temperature to developmental period in larva stage of the sugar-cane moth borer.*

Mean temperature.	Average period.	Number of records.	Mean temperature.	Average period.	Number of records.
°F.	Days.		°F.	Days.	
59.4	246.5	2	78.7	25	1
59.6	216	2	79.1	42	4
59.8	232.5	5	79.5	24	1
60	221	1	79.6	29	1
60.3	225	1	79.7	26	1
60.4	224	1	79.8	23.5	2
60.5	233	2	79.9	23	1
60.7	248	1	80	28	1
60.9	262	1	80.1	33	1
61.4	242	1	80.3	48.5	2
65.3	63	1	80.4	31	1
65.6	76	1	80.5	57	3
65.7	74	1	80.6	38	1
67.6	65	1	80.7	49	1
68.7	56	1	80.8	42	1
68.8	52	1	80.9	46	1

TABLE V.—*Relationship of mean temperature to developmental period in larva stage of the sugar-cane moth borer*—Continued.

Mean temperature.	Average period.	Number of records.	Mean temperature.	Average period.	Number of records.
°F.	Days.		°F.	Days.	
70	45	1	81	45	2
70.6	39	1	81.5	35.1	7
70.8	34	1	81.7	46	1
71.4	33	1	82	50	2
71.7	35	1	82.1	65	1
71.9	37	1	82.2	54.5	2
72	38	2	82.4	52	1
72.1	38.5	2	82.5	57.6	3
72.2	22	1	82.6	42.5	6
72.3	37	2	82.7	40.4	5
72.9	24	1	82.8	36	12
73.3	25.8	5	82.9	31.1	19
73.5	27	1	83	24.3	6
73.9	28	1	83.1	31	1
74	39	1	83.3	71	1
74.4	49	2	83.4	34	1
75.1	54	2	83.7	34	2
75.4	33	1	83.8	32.8	7
76.1	60.3	2	83.9	38.8	10
76.2	66	2	84	24	3
76.3	26	1	84.1	45.5	4
76.5	27	1	84.2	29.7	8
76.8	28	1	84.3	38.5	2
77.1	32	2	84.4	29.6	9
77.2	38	2	84.5	20.5	9
77.5	31	1	84.6	25.5	5
78	34	1	84.8	25.5	2
78.1	71	1	84.9	26.2	13
78.2	28	3	85	25	8
78.3	48	1	85.1	19	1
78.5	22	1	85.4	54	1

PUPAL CELLS.

When the larvæ are fully grown they construct a kind of pupal cell before pupating. The larval tunnel is cleaned, enlarged, and extended to the rind of the cane, where a small circular opening 4 to 5 mm. in diameter is made. The rind is not completely cut out, but it is eaten away from the inside until only a thin paperlike section, lightly attached at the edges, remains. This is held in place by threads of silk fastened to the inside so that the moth can easily escape, but other insects can not enter. The lower end of the cell is closed with frass and silk, and the whole cell is lightly lined with silk. In the rearing tubes in the insectary the pupal cell usually is formed on the side of the cane between it and the sides of the glass.

PREPUPA.

As the pupal cell nears completion the larva merges into the prepupa stage. No molt occurs, but the larva ceases feeding and becomes sluggish and helpless. The body contracts longitudinally, especially the thorax, while the use of the legs is lost and the insect thrashes about as do the pupæ. From 1 to 3 days are spent in the prepupa stage, but it often happens that this stage is not noticed by an observer, as it is not very distinct from the larva stage.

PUPATION.

After resting for a short time as a prepupa the pupa is disclosed by the casting of the last larval skin in the same manner as the others are cast.

PUPA.

The pupa at first is dirty white, about the same color as the hibernating larva, with faint purplish longitudinal stripes. It gradually hardens and darkens, and in an hour or two becomes mahogany brown. As the time for emergence approaches the pupa darkens more and may become almost black.

ACTIVITY.

The pupa is quite active when disturbed, being able to thrash about with its abdomen, which gives it a rolling, squirming motion. A touch or a jar will cause this action, as will also the placing of the pupa in direct sunlight in summer. Placed in the sun, a pupa squirmed about till it reached a shady place.

DURATION OF PUPAL PERIOD.

The first pupæ in the spring are formed from overwintering larvæ in April or May, and pupæ may be found from this date to December. Few larvæ pupate after the middle of November, those which have not pupated prior to this time hibernating as larvæ. Nearly 200 larvæ were collected in cane cut for the mill on December 2–4, 1915, but no pupæ were found in all the stalks cut open. Adults have emerged from pupæ in the insectary as late as December 5, but a large percentage of those which did not pupate until late and had the pupal period prolonged by cold did not emerge.

The pupal period, like that of the larva, has a wide variation, from 6 to 22 days being required for the emergence of the adult, with an average of 8½ days throughout the year. The pupæ which produced male moths required on an average 8.8 days for emergence, and those which produced females 8.4 days. Often there is a variation of 2 to 3 days among pupæ which transform on the same date. The data are presented in Table VI and figure 9.

TABLE VI.—*Relationship of mean temperature to the developmental period in the pupal stage of the sugar-cane moth borer.*

Period.	Average mean temperature.	Number of records.	Period.	Average mean temperature.	Number of records.
Days.	° *F.*		*Days.*	° *F.*	
5	77.1	3	13	71.6	1
6	82.3	27	14	79.7	7
7	81.1	153	15	73.9	5
8	81.3	92	16	77	5
9	80.9	42	17	72	1
10	76.6	19	18	69.8	1
11	76.1	12	19	84.6	3
12	74	4	22	63.7	1

DURATION OF THE LIFE CYCLE.

The length of the life cycle varies considerably with the temperature. Taking the minimum of each immature stage, the sum of 28 days is obtained, while in the same way a maximum of 293 days is

secured. The sum of the periods required by most individuals in the various stages is 43.1 days, which may be regarded as an average. The maximum larval period is 262 days and only occurs in hibernating larvæ.

SEASONAL HISTORY.

SEASONAL ABUNDANCE.

NUMBER OF BROODS OR GENERATIONS.

The variation in the time required for the development of the moth borer is so great that there are no distinct broods or generations. It is found that some larvæ require three or four times as long to reach the adult stage as others hatching from eggs laid at the same time,

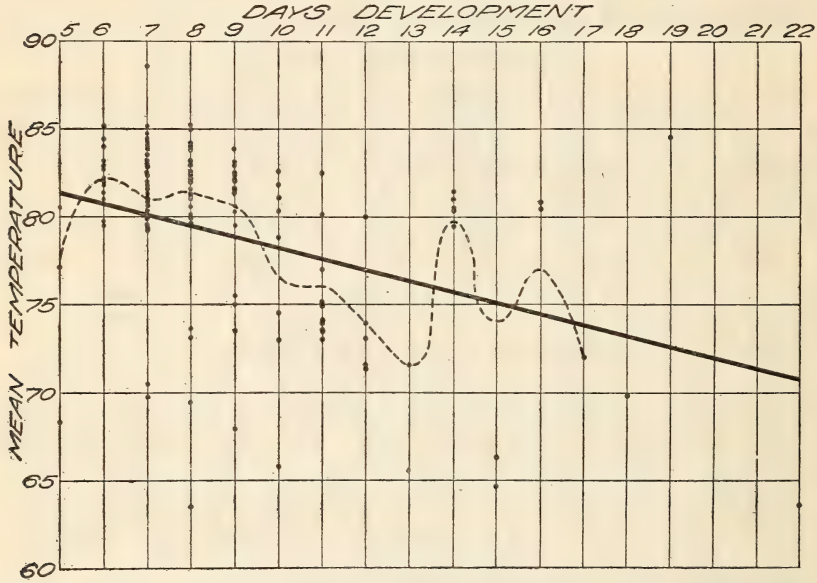


FIG. 9.—Diagram showing relationship of mean temperature to length of pupal period of the sugar-cane moth borer, showing line of calculated means (dashes) and general trend of means (solid line). The dots represent period means of individuals.

and this causes such an overlapping that the broods can not be distinguished.

The time of emergence of the moths in the spring varies from year to year, depending on the season. The earliest record is of a first-instar larva collected on cane in the field on May 5, 1914, and as the eggs require from 6 to 7 days incubation at this season the moth must have emerged during the last few days of April. The first emergence in the insectary was not until May 8, and emergence continued until May 25. Adults emerged from cane planted in boxes of soil as late as June 21. A pupa from the spring brood of borers was found in a "dead heart" on June 2, 1914. Thus adults from the hibernating larvæ and adults from the first spring generation are

emerging at the same time. This overlapping continues until by midsummer the broods can not be separated.

The maximum number of generations may be computed by taking the first eggs laid by each generation and assuming that they would develop under optimum conditions, thus reaching the adult stage in the shortest time possible at the prevailing temperature:

> The first eggs in the spring, laid by adults from the hibernating larvæ, would hatch by May 1 and the adults appear by June 10.
>
> Adults of the first generation would lay eggs June 11, and these would produce adults on July 24, after 43 days.
>
> Adults of the second generation would lay eggs on July 25, and these would produce adults on September 1, after 38 days.
>
> Adults of the third generation would lay eggs September 2, and these would produce adults on October 8, after 36 days.
>
> Adults of the fourth generation would lay eggs on October 9, and these would produce adults on November 18, after 40 days.
>
> Adults of the fifth generation would lay eggs on November 18, and the larvæ would hibernate and emerge in the spring.

On the other hand, it is equally possible for two generations to span the entire year, if we take the last to emerge from hibernation and allow them the maximum time for completing their life cycle. The latest record of emergence is June 21, 1914, and a moth emerging then would not oviposit before June 22 or 23. Eggs laid in the insectary June 25, 1914, required 90 days to complete their cycle, the adults not emerging until September 23. Larvæ hatching the latter part of August or in September frequently hibernate, so it is evident that the whole year could easily be taken up by two generations.

These data are based on rearing notes in the insectary and on observations in the field. While first-instar larvæ have been found in the fields from May 5 to the middle of December, and adults have emerged in the insectary in December, it is seldom, if ever, that the maximum number of generations are produced in the field. Most of the larvæ reared in the insectary have required from one and a half to two or more times the minimum length of time necessary to complete their life cycle, and there are usually only four, seldom five, generations. If the spring is early and other conditions favorable, there may be five generations, but if the spring is late and cold, as it was in 1915, there will be only four. In the Rio Grande Valley there is no true hibernation, although the stages are prolonged somewhat in winter, and in Cuba they are more nearly the same all the year around.

POSSIBLE ANNUAL PROGENY OF ONE PAIR.

It is on account of its rapid rate of reproduction that the borer is able to inflict enormous damage. As almost all the larvæ are killed in the fall by grinding the cane, and as there is a high mor-

tality among those which escape and hibernate, it is evident that comparatively few emerge in the spring. Yet there is always a heavy infestation by fall. The rapidity of reproduction during the warm months is the only factor which can account for this high infestation.

The record of oviposition for 56 moths at various times during the season of activity shows that each female moth deposits on an average 210 eggs. The sexes are produced in equal proportions. Allowing 200 eggs for each female and four generations a year as a conservative estimate, it is found that each pair surviving the winter is capable of producing the following numbers:

Generation.	Borers.
First	200
Second	20,000
Third	2,000,000
Fourth	200,000,000
Total	202,020,200

Of course this maximum number will never be produced, because of the numerous checks which control the insect, but something of its enormity may be realized by considering that if the offspring of one female were confined to 1 acre there would be over 10,000 borers per stalk of cane, about 20,000 stalks being the average per acre. Under average conditions about 50 per cent of the stalks are infested and about 25 to 30 per cent of the infested stalks contain borers when cut for the mill, giving from 2,500 to 3,000 borers per acre. Considering the possibilities, it is only surprising that the infestation is not much higher.

PROGRESS OF INFESTATION.

The moth borer is late in developing in the spring. The first "dead heart" at New Orleans is usually found about the 1st of May, which indicates that moths have emerged from hibernation several weeks previously. Not much injury can be found through the summer, but the numbers of borers gradually increase. When the cornstalks become dry in July and August the emerging moths undoubtedly migrate to sugar-cane fields in large numbers. The infestation increases rapidly from about this time until the cane is cut for grinding.

STATUS EXAMINATIONS.

Field examinations to determine the annual status of the moth borer and other sugar-cane insects have received considerable attention from the writers. The best and practically the only time to determine borer injury to sugar cane is during the grinding season

when the cane is cut, as the infestation increases up to this time and as the examinations necessitate the removal of the leaves from the stalk—a rather undesirable proceeding when the plant has still to make considerable growth. The plan adopted has been to examine at least 100 stalks in a field, sometimes many more. The uninfested and the infested stalks in these groups have been counted, and the percentage of infestation is determined from the data thus obtained. In actual practice this procedure has been modified. The number of fields examined in one vicinity seldom has been less than four, and often many more, depending upon the amount of time at the disposal of the inspector.

The infestation by the moth borer has been rather accurately determined year by year for the six years 1912 to 1917, inclusive, but the prevalence of other insect pests, which are not so important, has been only estimated.

To facilitate the inspections a card form was devised, which is reproduced here.

Form of card for field notes.

Sugar-cane Status, 191.... State..... Plantation.....

Locality..... Date..... Parish or county.....

Group examinations.	1	2	3	4	5	Total.	Per cent.	Owner, Location of field,
Stalks,								Year of crop,
Clean,								Variety, Soil,
Diatraea,								Cultivation,
								Sugar-cane condition,
Joints,								Stalks cut? Stalks standing? Trash burned?
Clean,								Aphis, Weevil,
Diatraea,								Lachnosterna, Ligyrus,[1]
								Ants, Pseudococcus,
Remarks:								Sugar-cane diseases,
								Environment,

Notes by.....

[1] *Ligyrus*= *Euetheola rugiceps* Le Conte.

AVERAGE ANNUAL INFESTATION IN LOUISIANA.

Observations have been made annually from 1912 to 1917, inclusive, on the infestation of from 6 to 13 localities in the borer-infested area of the Louisiana sugar-cane belt, with the result that the aver-

age annual infestation has been determined to be 58.2 per cent, or over half the canes infested. In 1912 the general average was 50.4 per cent, in 1913 it was 52.4 per cent, in 1914 it reached the high figure of 73.9 per cent, while in 1915 the average sank to 51.5 per cent. The average was again high in 1916, being 75.5 per cent, but in 1917 it was 48.8 per cent, the lowest during the six years. In some localities an infestation of 100 per cent is sometimes reached, or all canes infested, while in others the damage may be 30 per cent or lower.

Continuous observations have not been made in Texas, but in the lower Rio Grande Valley, to which the borer is limited at present, casual inspections usually reveal an infestation of nearly 100 per cent.

VARIATIONS IN INFESTATION.

The infestation of different fields of sugar cane in the sugar-producing region varies from a low percentage to 100 per cent, or every cane infested. Conflicting opinions are held by different planters as to the infestation of the different varieties of cane and the infestation in different years of growth. It has not been found that one common variety is more resistant to the moth borer than another, or that plant cane is more infested or less infested than first or second year stubble.[1] Another popular belief is that cane grown on sandy land is likely to be more heavily infested than cane grown on heavy soil. Examinations do not show that this is true, but the belief may have some basis, because it has been found that moths can emerge more readily from canes planted in sandy soil than from those planted in clay soil. The idea is also held that land treated with stable manure or cottonseed meal will be more heavily infested, but the data on the subject are insufficient to warrant any conclusion.

MANY LARVÆ CRUSHED IN THE MILL.

The greater number of moth borers in the larva stage in the late fall and early winter which would otherwise hibernate remain in the stalks of cane after they are cut. An examination of bored stalks at Audubon Park just before grinding yielded the information that 38 per cent of the stalks contained borers. When the stalks are ground in the mill these larvæ are crushed with the cane, leaving only such borers as may be in the stubble, seed cane, scraps of cane left about the plantations, cane tops, and Johnson grass and other grasses to start the infestation the following year.

[1] In 1918, however, 10,000 stalks of cane were examined on a group of six plantations, the examinations being well distributed and evenly divided between plant and stubble cane. It was found that the general average for plant cane on each plantation was invariably higher than for stubble, though there were wide variations among certain fields and parts of fields, both of plant and stubble cane. Examinations on a much smaller scale, made in previous years, did not indicate any difference in favor of either plant or stubble.

Because the species is so prolific, it is easily possible for a very few borers which remain alive in the spring to cause a high infestation over a whole plantation by the following grinding season.

NATURAL DISSEMINATION.

The moth borer has not been found to extend noticeably the limits of the area infested by it, as the cotton boll weevil does. The insect has never been found at Bunkie, La., though it has been observed at Melville, some 30 miles southeast, since 1914, and has probably been there for a much longer time.

ARTIFICIAL DISSEMINATION.

It is apparent that the infestation of new territory is caused principally through shipments of sugar cane, both for grinding and planting. The mature canes, if infested, contain larvæ or pupæ or both, and if left in a freight car on a railway siding, or if planted and imperfectly covered, the resulting moths can easily emerge. It is then an easy matter for the species to become established on such food plants as may be available at the time of year, and the infestation of adjacent cane fields may be expected within the next few years.

Infested seed cane was planted about 1909 above Baton Rouge on property which had previously been devoted to cotton farming and undoubtedly was not infested by the moth borer. In 1914 practically every stalk of cane was bored.

Introduction of new varieties of sugar cane should be left to experiment stations, and the cuttings should be subjected to special treatment and inspection (see "Immersion and fumigation," p. 49).

If cane is needed for planting or grinding by persons outside the infested area, great care should be taken to secure uninfested cane. Freight cars used for hauling cane may contain infested scraps which should be collected and destroyed at frequent intervals.

HIBERNATION.

STAGE OF INSECT THAT HIBERNATES.

The moth borer passes the winter in the larva stage. As fall approaches some of the larvæ go into hibernation, while others enter the pupa stage and emerge shortly as moths. There is nothing to indicate which of these two classes will hibernate and which will become moths. During the summer of 1913 some of the larvæ from eggs laid as early as August 13 went into hibernation, while others from the same mass of eggs completed their development as usual. Other larvæ from eggs laid August 18 and September 8, 22, and 27 died or hibernated, but larvæ from eggs laid September 1 and 18 completed their development and emerged in October and November.

One adult emerged in December from eggs laid as late as September 25, although the others from this mass of eggs hibernated. In general, it seems that most of the larvæ from eggs laid after the middle of September hibernate if they are not killed in the mill, but this depends somewhat on the season, as more will develop in a late fall. All instars of the larvæ hibernate. Small first and second instar larvæ have been seen as late as the middle of December crawling over the cane tops, and these would hibernate if they found suitable places. Hibernation is not what may be called complete, since the larvæ remain active on warm days and continue to feed to some extent. When infested cane is windrowed in the fall it is often badly damaged by the borers continuing their feeding throughout the winter, destroying many eyes and tunneling the stalks until they become brittle and break with handling. The well-grown larvæ continue molting at irregular intervals throughout the winter, but do not increase in size; in fact, they are even smaller and more flabby in the spring than they are in the fall. The small larvæ increase slowly in size and all hibernated larvæ are of a very uniform size in the spring.

PLACES OF HIBERNATION.

The larvæ hibernate in scraps of cane, tops of the cane plant, stalks of large grass, cane stubble, and planted and windrowed cane. Very few are to be found in stubble and grass stalks, however. No larvæ have been found in cornstalks during the winter, for these dry out and become unattractive to the moth borer long before cold weather begins. The usual place of hibernation of the closely related species *D. zeacolella*, however, is in the taproots of corn.

The favorite places of hibernation are scraps of cane left after grinding, and windrowed and planted cane. The windrow forms an ideal place for hibernation, the larvæ being well protected by the earth and the quantity of leaves covering the stalks.

EMERGENCE FROM HIBERNATION.

The hibernating larvæ pupate in the spring and emerge as moths when the cane is from a few inches to a foot or more in height. Though planted cane is covered with earth, this is often washed away by a heavy rain, exposing or partially exposing the seed cane. Moths have been found to emerge from cane under one-half inch of packed soil so that it is often possible for them to emerge from planted cane. There is of course no obstacle to their emergence from grass or cane stubble.

The times of emergence from planted cane under observation were May 7, May 21, and June 1, 1914, and the earliest emergence in the insectary was on May 8. A first-instar larva, however, was collected in the field as early as May 5, indicating that the parent moth must have emerged during the last few days of April.

SURVIVAL OF HIBERNATED LARVÆ.

Only a small proportion of the larvæ which go into hibernation survive the winter and emerge as adults. They die from time to time during the winter and those which have been in the larva stage for a long time seem to have trouble in pupating and often die in the attempt. Then, too, the mortality is higher among the pupæ from hibernated larvæ than from others, and the adults that emerge are not so vigorous.

Not more than 10 per cent of the larvæ kept under insectary conditions emerged, and as those pupating in the field often have the additional trouble of emerging through some depth of soil, it is evident that only a small percentage survives. On account of their rapid increase in numbers it requires only a few moths in the spring to produce a large number of borers during the summer and fall.

LONGEVITY OF HIBERNATED LARVÆ.

The usual larval period is greatly prolonged by cold weather or other adverse conditions, and the larvæ can survive great hardships. It is not at all uncommon for them to live for a month or two without food, and Stubbs and Morgan (152) have kept them for 75 days without food and had them pupate afterwards. Rosenfeld and Barber (137) kept a larva for 200 days without food and it pupated, while E. R. Barber records placing a larva in the photographic dark room on October 19, and finding it alive June 9, a period of 231 days, during which it did not feed on the piece of sugar cane provided. The larva stage of overwintering individuals is generally about 7 or 8 months, and during this time there are 10 or 12 molts, but in the authors' experiments some required 276 days and 14 molts to reach the pupa stage.

NATURAL CONTROL.

CLIMATIC CONTROL.

EFFECT OF RAINFALL.

Mr. George N. Wolcott, while entomologist of the Insular Experiment Station, Rio Piedras, Porto Rico, made a number of observations which tend to prove that the moth borer is adversely affected by rainfall. The following is an abstract of Mr. Wolcott's conclusions:

A large number of careful observations made in Porto Rico during the past grinding season, confirmed by the evidence from other countries, indicates that there is a constant relation between the amount of rainfall and the abundance of Diatraea. The table, which gives the percentage of infestation of cane by Diatraea in conjunction with the total annual rainfall in inches for 1914,

shows that the abundance of Diatraea is in inverse proportion to the amount of rainfall. (The table mentioned shows that the infestation varies from 6 per cent, where there were 101 inches of rain, to 66 per cent, where there were only 21 inches.) . . .

It is comparatively easy to demonstrate the effect of an abundance of rainfall in lessening the numbers of Diatraea, but much more difficult satisfactorily to account for this effect. The eggs of the borer are deposited on the leaves of the cane, and when the young larvæ hatch, a considerable interval elapses while they crawl about on the cane before they enter the stalk or the midrib of the leaf. It is quite probable that this is one of the most crucial periods in its life history, and that considerable numbers of borer larvæ were killed in young cane by the more rapid growth of the central shoot of a cane plant than of the outer leaves. Also, larvæ were found which had been drowned in a mixture of water and decaying cane juices which had collected in their tunnels after rains. To avoid danger from these causes, many larvæ were found living outside the shoot, where they were exposed to the attacks of predators or parasites.

The rainfall over the sugar belt of Louisiana does not vary to any great extent, and while there are annual differences both in infestation and rainfall at various points, a careful study of the subject has failed to prove that these variations correspond as they do in Porto Rico.

Below is given the infestation by the moth borer at various places in 1916 as compared with the annual rainfall.

Infestation by the moth borer compared with annual rainfall at various places in Louisiana.

Place.	Annual rainfall.	Canes infested in fall.
	Inches.	*Per cent.*
Donaldsonville	61.51	91
White Castle	50 to 60	99
Thibodeaux	50 to 60	79
Mathews	50 to 60	97
Palmetto	50 to 60	37 [1]
Franklin	58.89	53.5
New Orleans	55.37	38
Napoleonville	54.96	95
Lafayette	54.68	99
Melville	51.98	22
Abbeville	50.39	98
Morgan City	47.69	93.5

The period during which the growing cane is attacked by the borer in Louisiana is, roughly, from the month of April to the month of October, inclusive. A graphic comparison of the rainfalls during these months for the years 1912, 1913, 1914, 1915, and 1916 with the average infestations by the borer in the fall of each year is shown in figure 10. In some years the line representing infestation descends as the line representing rainfall ascends, but there were exceptions, especially in 1916, which the authors can not explain. Mr. Wolcott suggests that the small variation in the rainfall at different points

[1] Probably flooded.

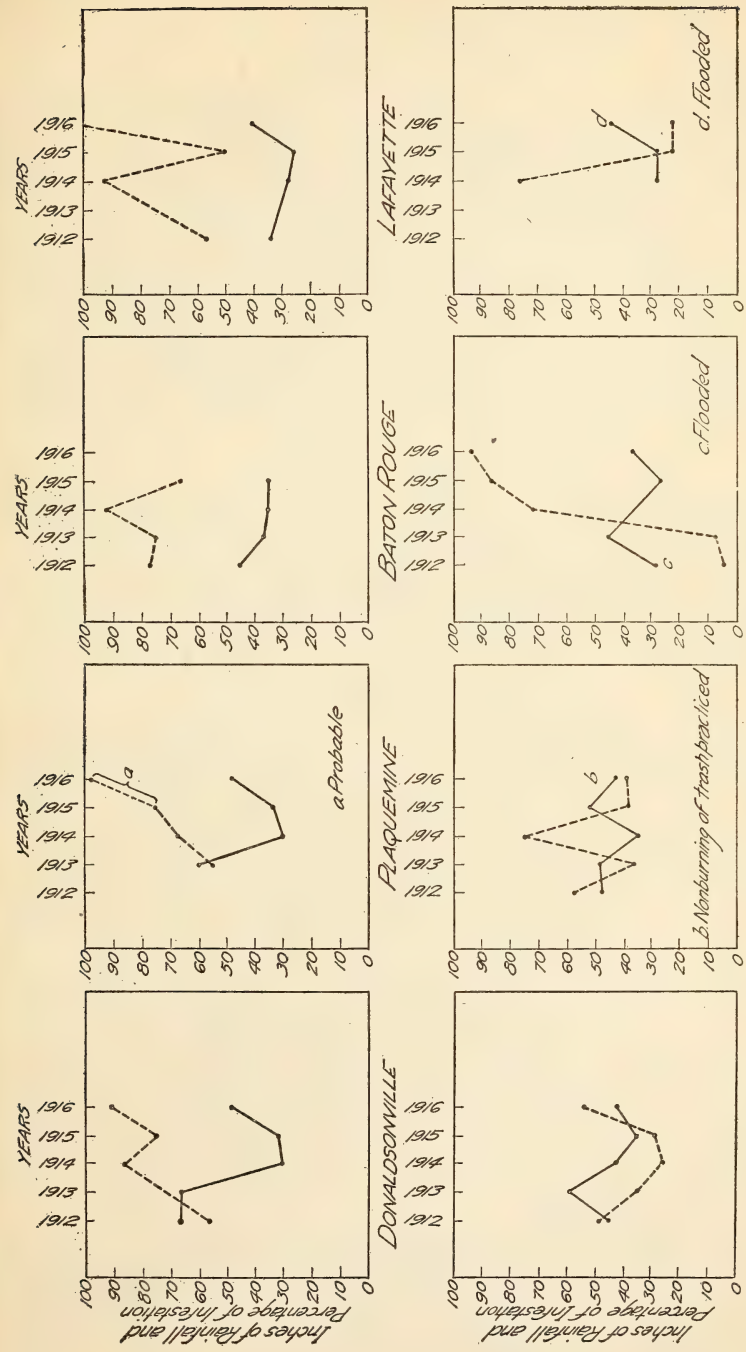


FIG. 10.—A series of graphs showing the nonrelationship of rainfall to infestation by the sugar-cane moth borer in Louisiana. Dash lines represent percentages of infestation and solid lines inches of rainfall from April to October, inclusive, the months of greatest activity.

in Louisiana as compared with Porto Rico makes it more difficult to determine its effect on the moth borer.

EFFECT OF FLOODS.

Complete flooding of cane fields for long periods seems to have a great influence on the infestation of the moth borer. For four years observations have been made on a plantation near Morgan City, which was under water for some weeks in the spring of 1912. In the fall of 1912 the infestation on this plantation was 4 per cent. In the fall of 1913 it was 6 per cent, only slightly higher than in the year of the overflow. In the fall of 1914, however, the infestation had reached 68 per cent, while in 1915 it was 87 per cent. It seems that the moth borer was much reduced in numbers by flooding, but that the numbers increased rapidly the second year after the inundation.

EFFECT OF IRRIGATION.

Though floods seem to reduce the percentage of infestation, it has not been observed that irrigation has any effect. Observations have been made on the nonirrigated plantations of Louisiana and on the irrigated properties of the lower Rio Grande Valley of Texas. No difference in the infestation which can be traced to irrigation has been noticed.

FUNGOUS DISEASES.

Although a fungous disease on the larvæ of *Diatraea saccharalis* was studied by J. R. Picard (120) at the Louisiana State University in 1903, its occurrence under natural conditions is very rare. Larvæ are sometimes attacked in the insectary, especially when kept in tin boxes, but all attempts to inoculate healthy larvæ have failed and it is probable that the fungus is only saprophytic. One such diseased larva of *D. zeacolella* sent in by Mr. A. G. Davis from Chipley, Fla., was submitted to Mr. Alden T. Speare, Mycoentomologist of the Bureau of Entomology. He reported that "the fungus seems to be very close to *Aspergillus parasiticus*, which I found to be parasitic upon the sugar-cane mealybug in Hawaii. There is no doubt that the fungus is an Aspergillus, but I would venture no specific name at present. *A. flavus* has been found to be parasitic upon sugar-cane mealybugs in Louisiana and in Porto Rico, but this is the first record to my knowledge of an Aspergillus on Diatraea, hence I can not vouch for its parasitism."

The fungus parasite *Cordyceps barberi* is recorded by Van Dine (169) from Porto Rico, and by Bodkin (17) from British Guiana on both the larva and the pupa of Diatraea. The present writers planned to experiment with this disease but they were unable to obtain cultures or diseased specimens.

PARASITES AND PREDACIOUS ENEMIES.

MOTH-BORER ENEMIES IN THE UNITED STATES.

Four parasites of species of Diatraea have been found in the United States, but three of them are extremely rare. The chalcis-fly *Trichogramma minutum* Riley is universally distributed in the sugar-cane fields of Louisiana and of the lower Rio Grande Valley of Texas, and is a very important factor in the control of the moth borer. It is a minute wasplike insect, the female of which deposits her eggs within the eggs of the borer, in the course of a few days numbers of adult parasites emerging from the moth-borer eggs.

A similar insect is the black parasite *Ufens niger* Ashmead, found near Brownsville, Tex., by the senior writer in 1912. This has not been found a second time, although Mr. George N. Wolcott made a special search for it extending over about two months in the summer of 1917. Vickery[1] records it as a common parasite of eggs of the leafhopper *Draeculacephala mollipes* Say, and it may attack Diatraea only rarely.

Parasites of the larvæ have not been found in Louisiana, but a braconid, *Microgaster* sp., has been reared from larvæ of *Diatraea zeacolella* Dyar, collected in corn by Mr. E. R. Barber at Bennettsville, S. C. A thorough search for larval parasites was afterwards made in South Carolina, Georgia, and Florida by Mr. A. G. Davis and the junior writer, but none was found.

Another braconid has been reared by Dr. A. W. Morrill, State entomologist of Arizona, from the species of Diatraea (probably *lineolata*) which occurs in that State.

Stubbs and Morgan (152) record a telephorid beetle, *Chauliognathus marginatus* Fabricius, as feeding on the larvæ. This is occasionally found in considerable numbers in sugar-cane fields in Louisiana.

During 1916 Mr. A. G. Davis found earwigs (Dermaptera) consuming larvæ of Diatraea in Florida, and in 1917 Mr. George N. Wolcott, in Texas, observed them feeding on eggs of *Diatraea saccharalis* which had previously been parasitized by *Trichogramma minutum*. It is unlikely that the work of earwigs is of any importance in control, and in feeding on parasitized eggs they would, of course, do more harm than good.

The Argentine ant (*Iridomyrmex humilis* Mayr) has been observed feeding occasionally on eggs, larvæ, and pupæ of the moth borer, but it can not be considered a factor in repression. The ants seem to attack only those eggs which have been parasitized, and while they may sometimes attack larvæ they will not ordinarily molest a

[1] Gibson, Edmund H. The sharpheaded grain leafhopper. U. S. Dept. Agr. Bul. 254. 16 p., 1 fig. 1915.

larva or a pupa unless it has been injured in some manner. The damage produced by ants in increasing the number of mealybugs, and as sugar-house and household pests, more than offsets any good which may come from their destruction of insects.

The Egg Parasite, Trichogramma minutum Riley.

On account of its economic importance *Trichogramma minutum* (fig. 11) deserves more extended consideration. It is almost microscopic, and belongs to the large order of Hymenoptera, which includes the bees and wasps. Under the microscope its wings are found to be fringed with delicate hairs and to have lines of these hairs running across their surfaces.

The adults are about one-fiftieth of an inch long, with a wing expanse of a little more than the length of the body. On account of their minute size they are practically invisible in a sugar-cane field, even though they may be present in great numbers. The best way to find them is to search for a cluster of moth-borer eggs which have turned black (indicating parasitism). During the summer, and especially in the fall, an experienced person can sometimes find these clusters in considerable numbers on the leaves both of corn and of sugar cane. If the eggs are put in a small tube and observed for a few days, many light yellow Trichogramma adults may be found to emerge.

In the fields the females of these parasites search for moth-borer eggs very soon after emergence. Finding a cluster, the female inserts her own eggs into the borer eggs, and in the course of eight days or longer, depending on the season, a new generation emerges, the parasites having developed from egg to adult within the moth eggs.

The parasites are scarce at the beginning of the season, and in fact eggs destroyed by them were never found earlier than June 18 in Louisiana. As the season progresses they become more and more abundant, until at last they destroy almost every egg cluster of the moth borer.

If the parasites could be so controlled that they would start their beneficial work earlier in the year, great good would result in limiting the ravages of the moth borer. Low temperatures retard the development of insects, and in an experiment to keep them over the winter parasitized eggs were placed in a refrigerator having a uniform temperature of about 50° F. Some of the parasites emerged even at this temperature, however, and all of them died during the winter.

Under natural conditions they undoubtedly hibernate in the cane trash left on the fields of the sugar plantations, at least until the trash is burned, when many of them are probably destroyed. This

practice is probably to blame for their scarcity during the following spring and early summer. To avoid the destruction of these beneficial parasites experiments have been conducted for the last five years in conserving the cane trash. The trash may be raked to the headlands or to waste land, or it may be plowed under. This subject is thoroughly discussed under the heading "Not burning cane trash," page 55.

MOTH-BORER ENEMIES IN FOREIGN COUNTRIES.

The minute egg parasite *Trichogramma minutum* occurs almost universally, having been recorded from Cuba, Porto Rico, Trinidad, British Guiana, Barbados, and elsewhere, as noted below. Another egg parasite, *Telenomus* sp., is recorded from British Guiana by Bodkin (17), who also records a braconid, a tachinid fly,[1] and a large chalcidid, *Heptasmicra curvilineata* Cameron. Two species of ants are mentioned by Bodkin as destroying the eggs. Predators in British Guiana are an elaterid and the histerid *Lioderma quadridentatum* Fabricius. From the same country Moore (104) lists *Iphiaulax medianus* Cameron, *Iphiaulax* sp., *Cremnops parvifasciatus* Cameron, and *Cremnops* sp. (all braconids), and the ichneumonid *Mesostenoideus* sp. From Trinidad Urich (164) records a sarcophagid fly[2] (probably parasitic) and a hymenopteron, *Cyanopterus* sp. The tachinid *Euzenilliopsis diatraeae* Townsend was found in Cuba by the junior author, as well as a species of Apanteles. *Tachinophyto* sp.[1] is recorded by Van Dine (170) from Porto Rico. Rosenfeld and Barber (137) record an intestinal worm, the braconid *Microdus* sp., and a dipteron[2] from Argentina. Van der Goot (58) states that in Java Diatraea is parasitized by *Phanurus beneficiens* Zehntner, *Trichogramma minutum* Riley, *T. nanum* Zehntner, *T. australicum* Girault, in the egg stage, and by a braconid and a tachinid[3] in the larva stage. He also records two species of ants attacking the pupæ and the eggs, and a small carabid feeding on the larva. De Charmoy (51) notes *Telenomus* sp., (*Ophion*) *Stauropodoctonus mauritii* Saussure, *Trichogramma australicum* Girault, *Ophion*

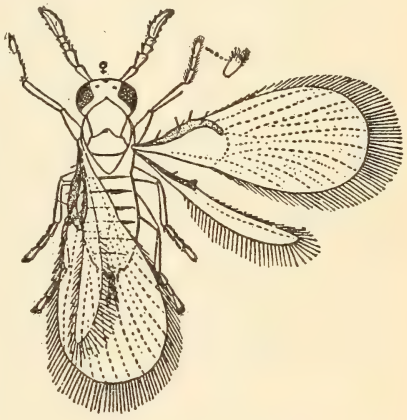


FIG. 11.—*Trichogramma minutum*, an egg parasite of the sugar-cane moth borer. Highly magnified. (Riley.)

[1] These flies are thought by Dr. C. H. T. Townsend to be probably his *Euzenilliopsis diatraeae*.

[2] According to Dr. Townsend Rosenfeld and Barber's "dipteron," and probably Urich's "sarcophagid fly," are *Oxysarcodexia peltata* Aldrich.

[3] According to Dr. Townsend this is *Diatraeophaga striatalis* Townsend.

(*Henicospilus*) *antankarus* Saussure, *Apanteles simplicis* Viereck, and a tachinid fly from Mauritius. Jarvis (83) states that *Diatraea saccharalis* "appears to be under effective natural control in Queensland," while Mr. Frederick Muir has told the writers that this is the case in the Philippine Islands also.

REPRESSION.

EXPERIMENTS AND OBSERVATIONS IN ARTIFICIAL CONTROL.

DESTRUCTION OF SCRAPS OF CANE LEFT AFTER GRINDING.

One of the chief places of hibernation of the moth borer is in scraps of cane left about the plantation. The wise manager will therefore collect such scraps as soon as possible after the grinding season and destroy them. On a plantation on which many scraps had been left about the mill and the derricks from one season to the next the infestation was practically 100 per cent over the whole plantation.

After the scraps are collected they may be disposed of by a very thorough burning with oil or some dry material. Throwing the scraps into a lake or other body of water is not to be recommended, as some of the moths may emerge from the floating stalks or from those which are washed ashore. Passing the scraps between the rollers of the mill has been recommended, but this would hardly be practicable on the ordinary plantation.

CUTTING OUT "DEAD HEARTS."

The dead plants, or "dead hearts," which follow the work of the moth borer in the spring, contain for a few weeks the larvæ which have killed them. A familiar recommendation has been to cut out these dead plants and burn them, care being taken to cut to or even below the surface of the ground so as to secure the larvæ.

The writers had an opportunity of observing this work in progress on a large scale at the State penitentiary farm at Angola, La., in the spring of 1917. The cutting of the "dead hearts" was being done very efficiently by convicts. They collected the dead plants in bags and burned them on the headlands. It was the opinion among the foremen that the "dead hearts" should be cut out of each field three times during the early growing season. One man was said to cover 4 acres per day.

The writers made a point of revisiting the penitentiary farm in the fall to ascertain the results of the work. It was found that the average infestation of the whole plantation was 31.5 per cent, which for 1917 was not extraordinarily low. Around Port Allen, La., for instance, the average infestation was 30.7 per cent, and the "dead

hearts" had not been cut out at that place. Individual fields at Angola ran from 6 to 85 per cent, and at Port Allen from 9 to 94 per cent.

It is possible that the different fields at Angola did not all receive exactly the same treatment as to cutting out the "dead hearts," especially as the plantation is divided into a number of farms or sections, each of which has its separate manager. As far as the authors could ascertain, however, the treatment had been uniform over the whole plantation.

It was the opinion of several of the farm managers that cutting out the "dead hearts" would not be practicable on a plantation where free convict labor is not available.

Moore (104) records the collection of 15,285,960 larvæ and pupæ of the moth borer on 17 estates in Demerara, British Guiana, in 1912, and 13,632,655 in 1911. He then remarks:

> The effect upon the pest of all this terrific slaughter has not as yet been very marked, but will increase more and more rapidly if the destruction be kept on persistently, systematically, and relentlessly. The insect propagates at such a very rapid pace, in spite of the counter-activity of a variety of natural enemies, and in spite of whatever may be the weather conditions, when its seasons come round, that to overtake it and bring it under proper control must needs be a rather long undertaking.

POISONING YOUNG PLANTS.

By covering the young plants with an arsenical in powdered form, which was suggested by the junior author, it was hoped to present a poisoned leaf surface to the first young borers of the year. Before gnawing into the plants the newly emerged larvæ feed among the leaf whorls for a limited time. It was thought that if they could then be poisoned much damage later on could be prevented.

A small preliminary experiment gave what seemed to be promising results, and in 1916 a large plantation experiment was planned. Fields on a typical plantation were poisoned one, two, and three times, powdered arsenate of lead being used, and the applications being made at many different dates in the spring. After nearly every application, however, there was a heavy rain, and the following fall no benefit could be observed. About 2 pounds of poison per acre were applied, a special horse machine being used.

The experience gained in 1916 had proved that the machine, which was designed for cotton, was not well adapted to sugar-cane fields. In 1917 the framework was strengthened and a gasoline engine added. This gave a much more uniform distribution of the poison, and an application of 2 pounds per acre covered the plants rather thoroughly. One man and a 2-horse team with this machine could cover 35 acres per day at a total cost for labor and material of

64 cents per acre. The apparatus used in the test is illustrated in Plate VII.

A 125-acre field at Belle Alliance Plantation near Donaldsonville, La., which was naturally divided into approximately 5-acre plats by drainage ditches, was selected for the experiment. One plat was poisoned once a week during the nine weeks from April 19 to June 14, while other plats received from one to four applications of 2 pounds per acre at weekly and fortnightly intervals, beginning at different dates during the nine weeks' period. The season was rather dry and rain did not interfere with the work any more than might be expected under Louisiana conditions.

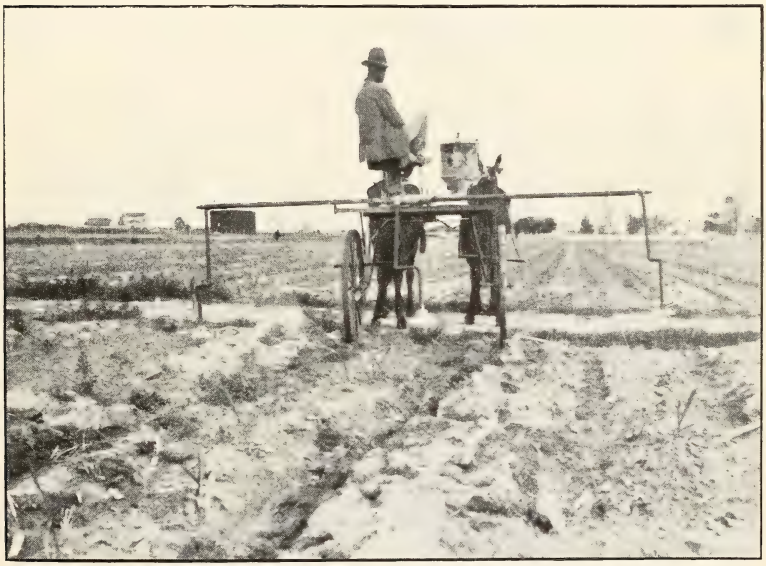
Borer eggs and "dead hearts" were observed throughout the spring and summer in the various plats, and in October, when status examinations were made, considerable variation was found in the different plats, but no relationship between the poisoning and borer infestation could be established, the treatment evidently having no effect whatever. This is probably due to the fact that the poison did not enter the central whorl or "throat" of the plants, where the young larvæ were feeding.

These experiments will indicate to the reader just how difficult is the control of the sugar-cane borer, and how inefficient are the usual methods of repression when used against it. For a long time the application of poison to sugar cane was regarded as hardly practicable, but when tried it was found to be not prohibitive as to cost or labor, although of absolutely no benefit.

REACTION OF ADULTS TO HONEY AND OTHER BAITS.

In the control of certain pests of vineyards in Europe, baits composed of fermenting molasses and other substances have been reported as successful in attracting the adults. In fact the use of these baits appears to be a well-established practice in some communities. It is also well known that collectors often make use of a mixture of stale beer or rum and brown sugar for attracting certain night-flying moths. It was thought worth while, therefore, to test the attraction of various chemicals and mixtures to borer moths.

Five modified flytraps were hung in cane and corn fields known to be infested. All the traps were baited with the same substance at a time, and were left in the fields for at least 24 hours. The following mixtures and chemical compounds were experimented with: (1) Honey; (2) honey, water, and alcohol; (3) 1 part honey dissolved in 3 parts alcohol; (4) stale beer, low-grade sugar, and alcohol; (5) stale beer and sugar; (6) oil of anise; (7) imitation strawberry sirup; (8) orange-flower sirup; (9) cedar oil; (10) solution of citric acid; (11) pyridin; (12) xylene; (13) vanilla extract; (14) oil of



POISONING YOUNG CANE PLANTS WITH POWDERED ARSENATE OF LEAD.

Poison was found to be unsuccessful in controlling the moth borer.

citronella; (15) oil of wintergreen; (16) oil of cinnamon; (17) formaldehyde solution; (18) pennyroyal; (19) fluid extract of valerian.

No borer moths and very few other insects were captured.

REACTION OF ADULTS TO LIGHTS.

Attracting the adults to lights has been proposed occasionally as a means of controlling the moth borer. It seems evident, however, that lights can exercise little attraction for them. The moths avoid the sunlight and remain concealed during the day in dark places, such as between the leaves and the stalk of a sugar-cane plant. If disturbed they fly for a short distance, seeking another place of concealment. As dusk approaches, however, they become very active, but daylight finds them motionless again.

Experiments have been conducted with insect light traps, which are so constructed that insects which fly to the light will be killed by a poisonous gas and fall into a jar, from which they may be removed at the convenience of the collector. A commercial moth trap was used. Some of the traps were fitted with glasses of various colors, so that they would throw colored lights, and they were equipped with electric lights of high candlepower in addition to the kerosene lamps with which they were furnished by the manufacturers.

In September, 1914, a light trap was placed about 20 feet from a plat of young corn which was heavily infested by the moth borer. A clear light of about 60 candlepower was used. The trap was run on 16 nights between September 16 and October 13. The catch of borer moths was as follows:

Sept. 16	4 males, 1 female.
Sept. 17	13 males.
Sept. 18	18 to 20 males, 4 females.
Oct. 6	1 male.
Oct. 9	4 males.
Oct. 10	1 male.
Total males	41 to 43.
Total females	5

Borer moths were caught on only about one-third of the nights during which the trap was operated, and practically no females were secured. The few females caught apparently had deposited their eggs already.

A much more elaborate series of experiments was conducted in 1915. From May 12 to June 18 five traps were operated with kerosene-oil lamps, the traps being fitted to throw lights of the following colors: Green, yellow, clear (uncolored), red, blue. As no borer moths were caught, the traps were provided with carbon-filament incandescent electric lights, 100 watts, 120 volts, candlepower about 80. A mottled brown and yellow glass was substituted for the yellow, which had

been broken. The traps were operated during July, August, and September, with the following results:

Clear glass	58 males, 2 females.
Mottled	26 males.
Green	18 males.
Blue	15 males.
Red	0
Total males	117
Total females	2

Neither of the females which were attracted to the clear light contained eggs.

The lights were arranged so that they were about 6 feet from a field of sugar cane. Observations were made to determine whether the number of canes infested by the moth borer had been lowered by the proximity of the lights, but this was not found to be the case, the infestation being as high as usual.

In 1916 more experiments were conducted, larger traps made on the same principle as those previously employed being fitted with glasses of standardized colors prepared for railroad semaphore lights. The colors used were purple, blue, red, green, brown, and clear. The electric globes were of the same type as those used in 1915. The lights were operated on 54 days from May 9 to September 4, the results being as follows:

Purple	5 males, 4 females.
Blue	5 males.
Red	0
Green	6 males.
Brown	1 male.
Clear	44 males, 2 females.
Total males	61
Total females	6

Experiments were conducted also on three nights in September with a 750-watt light taken into a cane field and operated by means of a long extension wire. This was suggested by Mr. E. R. Barber. It was observed that the moths would rise and then settle on the plants again, not continuing to fly around the light. Two males and five females were caught. There was some doubt as to whether two of the females had deposited their eggs, but the remaining three were certainly gravid.

The operation of lights was also observed on a certain Louisiana plantation on a much larger scale, gasoline torches being pulled about over the plantation. One was equipped with a gasoline engine and other apparatus which caused a powerful suction of air back of the light, the insects being sucked into an inner chamber. The other arrangement was a train drawn on the plantation railway,

consisting of a locomotive pulling a tank car filled with gasoline and a flat car bearing two huge gasoline burners, which produced flames 5 or 6 feet high. The lower parts of the flames were about 10 feet above the ground. The plantation management makes a practice of operating the train on favorable nights during the summer, and the expense in 1916 was said to be about $7 per night. On the night of August 25 the senior author saw both machines in operation and caught a total of 21 borer moths, of which 5 were males and 17 were gravid females. The moths would fly near the flame, their wings would be singed, and they would drop to the ground, or, in the case of the suction or vacuum outfit, they would be drawn with great force into the inner chamber. The fact that these machines were drawn through the midst of the cane fields may account for the variance of the results with those obtained with the light traps. As the lights were moved from one spot to another, group after group of insects was observed to rise. As soon as the insects had either settled or been captured or burned at one point the machines were moved a few yards farther on and a new group would start up.

It was expected that this plantation would have a low infestation in the fall. Fields were examined near which the lights had been operated and compared with other fields which had not been reached by them. The average infestation of canes was 96.7 per cent for the treated fields, while it was 97.3 per cent for the untreated fields, a difference of less than 1 per cent. The average infestation of all the fields examined as compared with the average infestation of other plantations in that part of the State not using the lights was higher rather than lower.

Even with the high percentage of females taken at the plantation lights it is apparent that with regard to percentage of canes infested the lights have no effect on the moth borer.

FALL PLANTING.

Windrowing seed cane for spring planting is a practice which affords the borer an ideal place to spend the winter. The insects can crawl from one stalk of cane to another in the windrow, killing many eyes which otherwise would germinate. The covering of earth and leaves protects the borer as well as the cane from the severities of winter.

Planting the cane in the fall instead of in the spring does away with the necessity for a windrow altogether, and is to be preferred. This is one of the recommendations of Stubbs and Morgan (152). Fall planting is practiced as far as labor and time will permit on most Louisiana plantations.

DEEP PLANTING OF SEED CANE.

To determine whether moths would emerge from planted seed cane, infested stalks were buried under various depths of soil in boxes which had been raised from the ground and isolated from ants. The soil used the first year was ordinary black soil found at the Sugar Experiment Station, Audubon Park, New Orleans, technically called "Yazoo clay." The cane was buried at the following depths: One-half inch, 1 inch, 2 inches, 3 inches, 4 inches, 5 inches, 6 inches. The soil was packed on the cane and the depths of earth were accurately determined. By covering the boxes with wire screen the capture of any emerging insects was assured. One female moth emerged from the cane buried under one-half inch of soil, while no moths emerged from cane buried at other depths.

This experiment was repeated the following year, using river sand as well as black soil (Yazoo clay) as before. The cane was buried at depths of one-half inch, 1 inch, 2 inches, and 3 inches. Three moths emerged from cane buried under one-half inch of river sand, while no moths emerged from cane buried at other depths. No moths emerged from any of the cane buried in the black soil.

The experiment indicates that the moths can emerge from cane under one-half inch of either clay soil or sand, more moths emerging from sand. Planters would, therefore, do well to keep the planted cane well covered with soil, especially in sandy land.

PLANTING BORER-FREE SEED CANE.

The old recommendation to plant borer-free seed cane is a very good one, providing borer-free seed cane can be obtaind. Ordinarily, however, it is not possible or practicable to obtain uninfested seed cane. The tendency among planters, too, is to grind the best cane and to plant the cane that is not too greatly injured, more cane being planted to a given area if it is somewhat inferior.

Planting borer-free cane has been found to give a better stand as compared to planting infested cane, but at least on a small area the subsequent infestation can not be expected to be reduced.

To determine the effect of planting selected cane, four rows were planted with borer-free cane and the adjoining four rows were planted with infested cane. The details of the experiment are shown in Table VII.

TABLE VII.—*Results from planting borer-free seed cane.*

Kind of seed cane.	Number of eyes at planting.	Plants on June 19.	"Dead hearts" on Sept. 1.
Borer-free	2,125	1,720	8
About 38.5 per cent infested	2,004	1,343	6

The senior writer was told by a reliable plantation manager of the planting of borer-free cane at Pharr, Tex., in 1916. Although there were no borers in the seed cane, which had been procured from a section known to have none, the cane was badly infested at the grinding season.

A field of cane planted with borer-free seed somewhat resembles a field of corn in its relation to borers. Undoubtedly there are often no borers in the cornfield when the seed is planted, yet there may be a heavy infestation later. The borer moths evidently fly into the cornfield during the early spring, and they can as easily fly into a field planted with borer-free seed cane.

SHAVING CANE STUBBLE.

Some sugar planters believe that "shaving" the cane stubble in the spring reduces the subsequent infestation by the moth borer. This operation is done with a "stubble shaver," a wheeled instrument having a straight or disk blade set horizontally, which cuts away the upper inch or so of the stubble. Borers are supposed to be in the upper portion, and when it is removed they are believed to be killed.

The authors' observations show, however, that few borers can be found in the stubble. Many stubble shavings have been examined, and no borers have been found in any of them.

It is apparent, therefore, that shaving the stubble can not be regarded as an effective measure for the control of the moth borer.

IMMERSION AND FUMIGATION OF INFESTED SEED CANE.

Various entomologists who have made a special study of insects injurious to sugar cane have experimented with hydrocyanic-acid gas and various liquids in attempts to disinfect seed cane before planting. In these experiments, the seed cane has been subjected to the gas in various strengths, and has been soaked in different solutions from one minute or less to at least three hours. The consensus of opinion at present seems to be that treatment of infested stalks is neither practicable on a large scale nor efficient as a means of controlling insects on an infested plantation.

At the Sugar Experiment Station at Audubon Park, New Orleans, all cane cuttings sent out are subjected to a rigid inspection and washing in fish-oil soap solution (½ pound soap to 1 gallon of water). Only cane not bored by the moth borer is sent out, and this is thoroughly washed in fish-oil soap solution to kill the mealybugs (*Pseudococcus calceolariae* Maskell), and afterwards is inspected to ascertain whether any mealybugs have escaped. This procedure results in the distribution of absolutely insect-free seed cane, which is highly desirable, as otherwise the experiment station would become a center of insect distribution.

On a plantation scale, however, such a treatment, even in a modified form, would be impossible. Experiments have shown that treatment of cane cuttings on a plantation already infested with the moth borer and the mealybug has little or no effect in reducing the subsequent infestation. In the season of 1911–12, a very great effort was made to eliminate sugar-cane insects from a small property in Louisiana. The trash on the fields was burned in the fall, the entire farm was given over to plant cane, no cane was windrowed, all cane was planted in the fall after having been dipped in a fish-oil soap solution (to kill the mealybugs), nearly all the stubble was removed from the fields (according to the plans *all* the stubble was to be removed, but the work was so difficult and expensive that some of the stubble was plowed under to a depth of 4 or 5 inches), and, finally, the planting of corn was delayed in the spring of 1912 so that any possible hibernated moths of the borer would not find corn as an early food plant. While the work may not have been done in an absolutely ideal way, the experiment was much more thorough than ordinarily would have been possible.

Even the weather seemed to cooperate to render the experiment a success. The winter of 1911–12 was cold, and the cane was late in sprouting in the spring, so that it seemed that there was no cane during the winter to serve as a food plant for the borers. Small borers were found, however, as early as May 24, 1912, and by October 17 the infestation ran as high as 75 per cent, with an average of 59 per cent. As to the mealybug, practically all the plants were infested. The experiment was evidently entirely negative in its results.

More exact experiments have been conducted to indicate the actual effect of fumigation and immersion on both the insects and the sugar-cane cuttings. Table VIII gives the results of dipping cuttings in various insecticides and fungicides and also of soaking the cuttings in the solutions for one hour, the borers afterwards being cut out to ascertain whether they were yet alive. The borers were kept and fed for about two weeks after the treatments.

TABLE VIII.—*Effect on moth-borer larvæ of immersion of infested cane cuttings.*

Solution.	Exposure.	Number of larvæ.	Condition of larvæ immediately after treatment.	Penetration of solution in cane cutting.	Condition of larvæ two weeks after treatment.
Bordeaux mixture 6–4–50	Dip	9	All alive	Penetrated, and was deposited on sides of holes.	7 alive.
	1 hour.	6	do	Some of the stalks were evidently full of the solution.	All dead.
Fish-oil soap, ½ pound per gallon water.	Dip	9	do	Evidently penetrated the stalks.	8 alive.
	1 hour.	11	All alive, 4 had emerged from cane and were in the solution.	do	9 alive.

TABLE VIII.—*Effect on moth-borer larvæ of immersion of infested cane cuttings*—Continued.

Solution.	Exposure.	Number of larvæ.	Condition of larvæ immediately after treatment.	Penetration of solution in cane cutting.	Condition of larvæ two weeks after treatment.
Nicotine sulphate (40 per cent nicotine), 1 part to 500 parts water.	Dip	10	9 alive, 1 small one dead between stalk and leaf sheath.	Probably penetrated the stalks.	4 alive.
	1 hour.	7	6 alive, 1 dead	do	All dead.
Potassium sulphid, 3 pounds per gallon water.	Dip	7	All alive	do	4 alive.
	1 hour.	10	do	do	1 alive.
Potassium sulphid 1½ pounds per 10 gallons water.	do	10	All alive, 1 emerged from cane and in the solution.	do	4 alive.

Soaking the cuttings for 1 hour in either Bordeaux mixture or nicotine sulphate solution was found to kill all the larvæ within 2 weeks. Only 1 larva was killed immediately, however, even after an immersion of 1 hour.

Eggs, larvæ, and pupæ were next subjected to immersions of 1 minute and 1 hour in the various solutions, with results as shown in Table IX. The larvæ and pupæ had previously been removed from the stalks of cane. A cluster of eggs, 5 larvæ, or 5 pupæ were used in each exposure.

TABLE IX.—*Immersion of eggs, larvæ, and pupæ of the moth borer in various solutions.*

Solution used and stage of insect.	Exposure.	Effect within 2 days.	Effect within 10 days.
Bordeaux mixture:			
Eggs	1 hour	Did not kill	All hatched.
Larvæ	1 minute	do	2 dead out of 5.
Do	1 hour	do	None dead.
Pupæ	do	do	All emerged.
Fish-oil soap:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	1 dead out of 5.
Do	1 hour	do	2 dead out of 5.
Pupæ	do	All killed	
Nicotine sulphate (40 per cent nicotine):			
Eggs	do	None hatched	All dead.
Larvæ	1 minute	Did not kill	1 dead out of 5.
Do	1 hour	do	Do.
Pupæ	do	do	All emerged.
Potassium sulphid, 3–100:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	None dead.
Do	1 hour	do	1 dead out of 5.
Pupæ	do	do	All emerged.
Potassium sulphid, 1½–100:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	1 dead out of 5.
Do	1 hour	do	All healthy.
Pupæ	do	do	All emerged.

Untreated eggs used as a check hatched as usual. Of 5 untreated larvæ, 1 died within 10 days. All of the 5 untreated pupæ were alive at the end of 10 days.

It will be noted that pupæ immersed for one hour in fish-oil soap solution were killed, while eggs immersed for one hour in nicotine-sulphate solution did not hatch. The other solutions were ineffective. It is evident that larvæ and pupæ are more seriously affected by these

two dips when in the cane stalks than when they are first taken out and then immersed. The reason for this is that a certain amount of fluid remains in the tunnels after the stalks are removed from the solution, and continues to affect the insects.

To test the effect of immersion and fumigation on the germination of cane cuttings, a number of tops and bottoms of the varieties D74 and Louisiana purple were treated in the fall and planted in the experimental fields. Table X shows the number of healthy plants on May 13 and at the grinding season. The "dip" was a very thorough immersion of the cuttings. Fish-oil soap solution apparently increased the percentage of germination, while no treatment can be regarded as injurious. Table XI shows the weight of cane in pounds of cane from the treated seed at grinding. The fish-oil soap solution appears to have increased the tonnage, though this result is doubtful.

TABLE X.—*Germination of treated seed cane.*

Treatment.	D74.		Louisiana purple.	
	Tops.	Bottoms.	Tops.	Bottoms.
Check (not treated)	[1] 18–73	20–79	44–89	36–71
Bordeaux mixture, dip (6–4–50 formula)	21–81	22–82	45–88	42–87
Bordeaux mixture, 1 hour immersion (6–4–50 formula)	26–94	28–88	46–86	29–81
Fish-oil soap, dip (one-half pound per gallon of water)	34–94	26–91	37–95	39–72
Fish-oil soap, 1 hour immersion	44–119	31–89	49–94	38–91
Check (not treated)	14–85	21–90	45–93	51–79
Tobacco extract (40 per cent nicotine as sulphate), dip (1 part to 500)	26–73	21–74	36–95	53–86
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion (1 part to 500)	39–100	31–86	55–88	48–85
Potassium sulphid, 3 pounds to 100 gallons of water, dip	d2–100	29–91	46–123	51–90
Potassium sulphid, 3 pounds to 100 gallons of water, 1 hour immersion	43–108	34–87	53–108	37–70
Potassium sulphid, 1½ pounds to 100 gallons of water, 1 hour	35–118	26–91	45–112	42–94
Hydrocyanic-acid gas, 1 hour fumigation (1 ounce, 20 cubic feet, 1–2–4 formula)	39–103	[2]	53–96	41–77

[1] Number of healthy plants on May 13 (first figure) and number of stalks at the grinding season (second figure), the seed cane having been subjected to various treatments before planting.
[2] Seed cane taken by unknown person.

TABLE XI.—*Weight of cane grown from treated seed cane.*

Treatment.	D74.		Louisiana purple.	
	Tops.	Bottoms.	Tops.	Bottoms.
Check (not treated)	[1] 160	192	230	160
Bordeaux mixture, dip	154	208	208	194
Bordeaux mixture, 1 hour immersion	188	164	214	184
Fish-oil soap, dip	224	204	226	176
Fish-oil soap, 1 hour immersion	238	220	212	214
Check (not treated)	158	238	214	188
Tobacco extract (40 per cent nicotine as sulphate), dip	142	138	168	158
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion	168	158	178	138
Potassim sulphid, 3 pounds to 100 gallons of water, dip	158	158	228	148
Potassium sulphid, 3 pounds to 100 gallons of water, 1 hour immersion	178	164	188	134
Potassium sulphid, 1½ pounds to 100 gallons of water, dip, 1 hour immersion	166	164	154	184
Hydrocyanic-acid gas, 1 hour fumigation	204	[2]	212	156

[1] Weight of cane in pounds at the grinding season is indicated by the numbers, the seed cane having been subjected to various treatments before planting.
[2] Seed cane taken by unknown person.

After the development of vacuum fumigation by Mr. E. R. Sasscer, of the Bureau of Entomology, a method which has proved highly efficient in the destruction of insects in seed and cotton bales, it was planned to fumigate cane by this system. It was a matter of general surprise that larvæ of the moth borer came out uninjured, even when subjected to a strong fumigation (6 ounces sodium cyanid, 9 ounces sulphuric acid, and 18 ounces of water to 100 cubic feet) for 1 hour, a vacuum of 25 inches being applied for 15 minutes and a normal air pressure for the succeeding 45 minutes, the combination of reduced air pressure followed by normal pressure having been found very satisfactory for most species.

DESTROYING OLD CORNSTALKS.

Some sugar planters believe that if it were not for the growing of corn on the plantations there might be little damage from the moth borer in sugar cane. They reason that the borer finds an acceptable food plant in corn before the sugar-cane plants are large, and that if corn were eliminated the emerging moths in the spring presumably would die.

Careful observations, however, show that the young cane plants are attacked as early as corn in the spring, if not before. In fact, the authors have always found borers in cane before they have observed them in corn. It is true that the moths emerge from the cornstalks in summer and fly to cane fields to deposit their eggs, the dry corn plants no longer being attractive. But if there were no corn the borers could, and many of them do, reach maturity just as easily in sugar cane.

Corn is not grown in Porto Rico, except in one isolated locality, according to Mr. George N. Wolcott, formerly entomologist of the Insular Experiment Station of Porto Rico. Yet a very high infestation is often found in sugar cane.

It is probable that the elimination of cornfields from Louisiana sugar plantations could have little or no effect on the numbers of borers, but if the cornstalks could be destroyed before the borer moths leave them a large number might be killed and the subsequent infestation reduced. Borers have not been found in the dry stalks at harvest, however, and the destruction of the stalks earlier than midsummer would be impracticable, unless a specially early-maturing variety of corn should be developed. The suggestion has been made that the cornstalks be destroyed during the winter; but the moths leave them many months before cold weather.

In this connection it is worth noting that very late corn is often ruined by the ravages of the larvæ, the moths from the earlier corn

and from cane depositing their eggs on the young corn plants as well as on the cane.

BURNING CANE TRASH.

In the process of harvesting sugar cane the tops of the plants and the lateral leaves are cut off and left in the fields, forming a quantity of fibrous vegetable matter almost universally called "the trash." (Pl. VIII, fig. 1.) A common recommendation has been to burn this débris as soon as it is dry enough, which is within a few weeks after the cane has been cut. Apparently burning would tend to decrease the subsequent infestation by the moth borer, but this has not been found to be the case. Examinations of the trash indicate that comparatively few borers are usually to be found in it, most of them being in the stalks of the cane, which are carted from the field and ground in the mill, thus disposing of the greater number. On the other hand, the trash is a favorable hibernating place for numbers of dipterous and hymenopterous insects, many probably of beneficial species. The eggs of the moth borer are deposited on the leaves of the cane plants, and these are attacked by the egg parasite *Trichogramma minutum*. It is probable that these minute beneficial insects are destroyed in great numbers when the trash is burned.

Louisiana sugar-cane planters have been burning over their sugar-cane fields for many years (Pl. IX, fig. 2), and it has not been found that any reduction in the number of canes infested by the moth borer results. Trash burning and other methods of control formerly recommended were thoroughly tried out on a plantation in Louisiana some years ago (see "Immersion and fumigation of infested seed cane," p. 49), but without beneficial effect. It is the opinion of the authors, after having made many field observations, that trash burning can not be expected to diminish the number of canes infested, while it may increase the infestation by destroying beneficial insects. An objection to trash burning, admitted even by its advocates, is that ordinarily it is not thoroughly done. The dry leaves which burn readily are consumed, and in the fields are left short scraps of cane, which sometimes contain living borers, even though they have been considerably heated and charred by the fire. It is evident that trash burning, while unquestionably destroying many beneficial insects, frequently fails to destroy the few borers left in the field, because of their protected situation in scraps of cane which do not burn readily.

When it is remembered that there are four or five generations of borers per year, that about half of the adults are females, and that each female lays an average of 200 eggs, it will be realized that a very few borers passing the winter successfully are sufficient to infest a whole plantation, especially if their parasites have been destroyed.

NOT BURNING CANE TRASH.

To protect the egg parasite the senior author some years ago began experimenting in disposing of cane trash by plowing it under and by raking it to the headland.

On one plat at the Sugar Experiment Station, Audubon Park, New Orleans, the cane trash was burned in the fall of 1912 as usual, while on another plat of about the same size the trash was raked to the headlands in the spring before cultivation. Through the growing season of 1913 careful examinations were made to ascertain the infestation in the two plats, and even in the spring and early summer the results were promising. For a long time no borers were found in the unburned plat, whereas borers and "dead hearts" were found in the burned-over plat, but when the cane was cut in October, the difference was most striking. In the burned-over plat 67.5 per cent of the canes were infested by the borer, while in the unburned plat only 15.5 per cent were infested.

On a plantation in the lower Rio Grande Valley of Texas no cane trash was burned in the fall and winter of 1912–13, while on neighboring plantations under the same management the trash was burned in the fall as usual. When examinations were made in the fall of 1913 the difference in infestation was easily discernible. The average infestation of the unburned fields was 30.6 per cent, while the average infestation of the burned-over fields was 76 per cent. In 1912 the average infestation of these plantations was 50.5 per cent and in a field a few miles away it was 86 per cent.

In 1914 various experiments were conducted at Audubon Park. Trash was burned in the fall, burned in the spring, raked to the headland in the spring, and plowed under in the spring. The results of these experiments are recorded in Table XII.

TABLE XII.—*Nonburning experiments, Audubon Park, New Orleans, La., 1914.*

Kind of treatment.	Number of plants infested by borer, May 29 to June 2, 1914.	Number of plants killed by borer, Oct. 28 to Nov. 2, 1914.	Per cent of canes infested by borer, Nov. 2 to 5, 1914.
Trash left on field in winter and plowed under in spring	3	3	45.73
Trash left on field in winter and raked to headland in spring	6	12	63.31
Trash burned in fall as usual in Louisiana	5	38	83.79
Trash left on field in winter and burned as soon as possible in spring	20	6	69.44

NOTE.—The plants infested May 29 to June 2 ("dead hearts") were cut out and destroyed about June 10, so that the plants killed by October 28 to November 2 were different plants which had been infested later in the season. The dates refer to the times examinations were made.

In each of these plats there were about 20 rows of cane. Three plats were in one field, not separated in any way, while the plat on which the trash was burned in the spring was separated from

the plat on which it was burned in the fall by a plantation roadway about 20 feet wide. Needless to state, these conditions were not of the best for the experiments. It would have been better if each plat had been comparatively isolated from other plats of cane so that there would have been no danger of the insects going from one plat to another.

It will be noted that the infestation at the end of May was almost negligible in all plats, but even then the least injury was in the plat where trash was plowed under in the spring. By October 28 the most conspicuous injury ("dead hearts" and large plants killed) was small, but the difference between the plats subjected to different treatments is notable. Again, the smallest number of killed plants (3) was found in the plat where trash was left on the field in the winter and plowed under in the spring. Fall burning gave as many as 38 plants killed. In the plats where the trash was raked to the headland in the spring, and where it was burned in the spring, there were 12 and 6 dead plants, respectively—several times more than where the trash was plowed under in the spring. A few days later, when the cane was cut, a careful examination was made of over 600 canes in each plat. Where the trash was burned in the fall the infestation was nearly 84 per cent, but where the trash was plowed under in the spring it was only about 46 per cent. The experiments in raking the trash to the headland, and in burning it in the spring, gave about 65 and 69 per cent, respectively. From these experiments spring burning seems to be better than fall burning, and plowing the trash under in the spring better than either. (Pl. VIII, fig. 2.) Raking the trash to the headland, for some unknown reason, did not give as good results in 1914 as it did in 1913.

Extensive experiments on plantations in Louisiana were carried on in 1915, 1916, and 1917. During 1915 and 1916 the results were negative, the infestation being about the same on fields where trash was not burned as where it was burned. The fields not burned were usually in the midst of other fields which had been burned over. Yet in 1916, when the trash was not burned except on one field at Audubon Park, the infestation was much lower there than anywhere else in the State, with the exception of two places which had been flooded. The average infestation in Louisiana for 1916 was 75.5 per cent, while the infestation at Audubon Park was only 38.3 per cent.

The reason for the difference between the results on plantations and those at Audubon Park was not understood until it was suggested in 1917 by Mr. W. G. Taggart that the relative isolation of the fields at Audubon Park had prevented the reinfestation of the unburned fields by moths flying from other plantations. This explanation seems to be correct, and the latest results tend to confirm it. The average infestation in Louisiana in 1917 was 45.8 per cent,

FIG. 1.—SUGAR-CANE FIELD AFTER THE CANE HAS BEEN CUT AND REMOVED, SHOWING HEAVY COVERING OF LEAVES OR "TRASH."

FIG. 2.—SUGAR-CANE FIELD SHOWING LEAVES OR "TRASH" PLOWED IN. THE STUBBLE WAS PLOWED UP IN THE SAME OPERATION.

CONTROL OF THE SUGAR-CANE MOTH BORER.

FIG. 1.—PARTIALLY COVERING CANE TRASH WITH TWO FURROWS TO A ROW TO HASTEN DECOMPOSITION DURING WINTER.

FIG. 2.—BURNING CANE TRASH.

as compared with 20.3 per cent at Audubon Park, where the trash was not burned on any of the fields but one. Comparing this burned-over field with an average of the other stubble fields, we have an infestation of 38 per cent for the burned-over field, while the average infestation of eight unburned stubble fields was 20.2 per cent, with 36 per cent as the highest infestation on an unburned field.

The plantation results in 1917 are in accord with the theory that isolation of fields influences the results of nonburning, using the term "isolation" to mean not only a situation detached from other cane plantings, but one separated from plantations where the trash is burned. In a locality in the midst of the sugar parishes, a typical plantation (designated *A* on the diagram, fig. 12), fronting on the Mississippi River and running back to swamp land was not burned over, the trash being plowed under in the fall. This plantation was bordered on the north by a burned-over plantation (*B*), and on the south by a much smaller plantation (*BB*), a long and narrow strip of land which had also been burned over. But bordering these plantations was one on the north (*C*) in which only part of the trash had been burned, the rest having been plowed under, and one on the south (*CC*) treated in the same way. Plantation *A*, where the trash had not been burned, while bordered on each side by burned-over areas, was yet the center of a district where much of the trash had been saved. The infestation at *A* was 22.5 per cent, and at *C* and *CC* it was 56.9 per cent and 53.6 per cent, respectively. At *B*—burned over, but between *A* and *C* and undoubtedly influenced by the trash saved at those places—it was 49.5 per cent. Plantation *BB* was over-

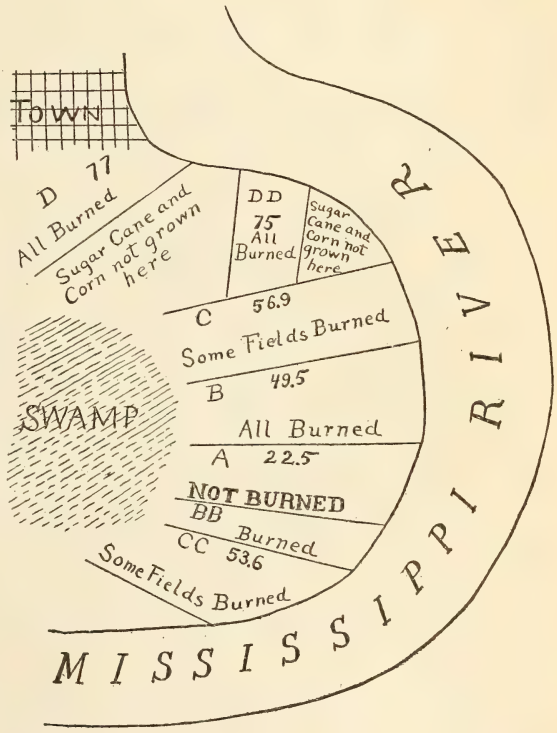


FIG. 12.—Diagram of plantations showing percentages of infestation by the sugar-cane moth borer in relation to nonburning of cane trash.

looked and the infestation is not known, but at two places in the vicinity, *D* and *DD*, both burned over, the infestation was 77 per cent and 75 per cent, respectively. The map will convey a more accurate idea of the situation than any further explanation, but the following points should be noted: At the two burned-over plantations, *D* and *DD*, farthest away from unburned fields, the infestation was high, about 75 per cent. At the two partly burned plantations, *C* and *CC*, it was medium, about 55 per cent. At the burned-over plantation *B*, bordered on each side by unburned or partly burned fields, it was also medium, 49.5 per cent. At plantation *A*, not burned and the center of a nonburning region, the infestation was the lowest of all, only 22.5 per cent.

It is evident that a plantation must be considered as a unit in determining the infestation. The former custom was to consider a field as a unit, to which there is the objection that the moths of the borer can fly readily and doubtless reinfest areas in which the parasites have gained the ascendency. Although a comparison of fields at Audubon Park is not unsatisfactory, it is true that the fields there are small, and they are not surrounded by vast stretches of cane and cornfields which are typical of the sugar parishes.

The results in 1917 indicate that nonburning will be effective on isolated areas of any size and on nonisolated areas so large that the bordering burned-over fields will have little effect on the general infestation. An illustration of nonburning on a single narrow plantation surrounded by burned-over areas was obtained in 1917. In this case nonburning was apparently of no benefit, the infestation being slightly, if any, lower than at a neighboring place. Yet the benefit to the land of plowing under the trash is considerable, and as it is only by degrees that the new practice will become established no planter should hesitate to practice nonburning because his neighbor refuses to do so.

A planter who has plowed under his trash tells us that it maintains the tilth of the soil from year to year, and the difference between the condition of the soil where trash has been plowed under and where it has been burned is immediately perceptible. Where the trash is plowed under the soil is left open and porous and is enriched by the nitrogen and other fertilizing elements of the decaying vegetation. (See Pl. IX, fig. 1.)

The work of plowing out the trash in the spring is regarded by some planters as so great that they refuse to leave it on the fields unburned. At the Sugar Experiment Station the process of caring for the trash, quoting Mr. W. T. Taggart, assistant director, is as follows:

> In plowing under cane tops, especially on land where stubble is to be held for the following year, the work must be done in such a manner as not to

injure the ratoons, and at the same time to hasten decomposition of the trash. The last object can be best attained by covering the tops with two furrows by the turning plow, before the green material has dried out. If the labor and teams are not available at the time, it is next best to do the plowing when the tops are as wet as can be handled without danger of damaging the mechanical condition of the soil. We find that two furrows, run as far away as possible from the old ratoon, and at the same time just deep enough to cover the trash lightly, are satisfactory. This practice practically allows all trash to be held continuously in a moist condition with free access to air, thereby hastening oxidation and decomposition. The partially decomposed vegetable matter is thoroughly and deeply buried at the usual time in early spring when cane is off-barred. Under average conditions of tonnage and winter rainfall we have found that cane trash treated according to this method will decompose sufficiently to allow cultivation of the middles without undue cost or inconvenience. However, when a heavy crop of tops has been turned under considerable difficulty may be experienced in throwing out the middles, unless the job is undertaken in two operations. First, whatever implement is assigned to this task should be run in such manner as to skim over the main layer of trash; the second furrow can then go deep enough to undermine any trash which has not been decomposed, and divide it along the side of the two rows where the following cultivation, preferably with a disc cultivator, will completely mix all this organic matter, with its humus and nitrogen, into the seed bed.

Practically the same method is used on the large plantations where the trash was left in 1916 and 1917. The labor of the first cultivation was said by one plantation manager to be about doubled and to cost about $1 more per acre than cultivation after burning. A plantation owner estimates an additional cost of $1.50 per acre. This is a very small amount to spend for the possible control of the moth borer, and is slight as compared with a maximum loss of nearly $50 per acre. Stubbs (151) calculates that for every ton of cane there are left in the trash 1.9 pounds of nitrogen, equal to the nitrogen in 27 pounds of cottonseed meal, while Mr. Taggart has told the writers that there are 556 pounds of organic matter in the trash per ton of cane. All this nitrogen and organic matter is lost in the burning of the trash, but preserved when it is buried. Considering the chemical and mechanical benefit to the soil, the possible insect control really costs nothing at all.

On the subject of nonburning, Prof. F. S. Earle (46), formerly director of the Cuba Experiment Station, writes as follows in the *Cuba Magazine:*

To the general burning of the trash in the fields after cutting there are, however, many valid objections under conditions existing in Cuba and Porto Rico. On many soils this trash is badly needed to keep up the supply of humus, but more particularly it is needed as a mulch to protect the soil from excessive drying out during our long periods of winter drought. Aside from this, the universal burning of the trash would involve an amount of summer cultivation to keep down weeds and grass that would be entirely beyond the present equipment and labor supply of most of our plantations. In other words, it is impracticable. The best we can hope in the direction of ratoon cultivation is to move the trash and cultivate alternate middles. Nor is there any reason to sup-

pose that burning the trash would give us any real protection from the borer. Cultural conditions in Louisiana are so different from ours that the burning of the trash is practically a necessity and it is universally practiced.[1] We do not, however, find that this gives them any immunity from the borer. On the contrary, they suffer fully as much as we do. This very likely may be due to the fact that burning destroys borer parasites as well as borers. There is good reason to believe that here in the West Indies borer parasites of one kind or another are sufficiently abundant to play an important part in holding this pest in check. There is no point more urgently in need of careful investigation. Until it is fully determined it will be impossible to outline a really satisfactory campaign against the cane borer. * * * On certain fields it becomes advisable to burn the trash in order to be able by thorough cultivation to kill out pernicious grasses that would otherwise ruin the fields. When and where and how much to burn are questions that must always tax the best judgment of the administrator. If judiciously done on a small scale it is often an advantage, but if universal burning of the trash should be adopted on the advice of our scientific friends it would surely result in the financial ruin of the majority of the plantations in Cuba and of many in Porto Rico.

It is believed that Prof. Earle will be proved correct in concluding that burning or not burning trash is a matter for the mature judgment of the plantation manager, in Louisiana as well as in other countries.

EXPERIMENT WITH THE HAWAIIAN BEETLE BORER PARASITE.

The work of the entomologists of the Hawaiian Sugar Planters' Association Experiment Station is too well known to need any extended description. Suffice it to say that under the auspices of the very progressive sugar planters of Hawaii the world was searched for parasites of insects destructive to sugar cane; that they found many parasites; and that they succeeded in establishing many of them in the cane fields of Hawaii. The injury from insects has been greatly reduced and millions of dollars' worth of sugar is being saved annually.

The parasite which contributed largely to the control of the weevil borer (*Rhabdocnemis* [*Sphenophorus*] *obscurus* Boisduval) was a tachinid fly (*Ceromasia sphenophori* Villeneuve) which was brought from New Guinea. As the habits of this beetle borer in boring through the cane stalks are much the same as those of the moth borer in Louisiana, the junior author suggested that Ceromasia be tried against the moth borer. The same suggestion was made later by Dr. L. O. Howard and Dr. W. D. Hunter, of the Bureau of Entomology. Mr. Frederick Muir, of the Hawaiian Sugar Planters' Experiment Station, who had discovered the parasite and introduced it into Hawaii, was consulted, and gave his opinion that it would not attack the moth borer. He stated that he had seen the moth borer (*Diatraea* sp.) and the beetle borer working together, and that Ceromasia confined itself to its beetle host.

[1] Prof. Earle is writing of conditions in Porto Rico and Cuba, with which he is more familiar, and takes it for granted that burning the trash in Louisiana, at that time universally recommended, is a necessity.

The writers were prevented from introducing parasites known to attack the moth borer in Cuba, however, and it seemed worth while to give Ceromasia a trial. A cage isolated from ants was arranged, and in 2 feet of soil at the bottom of this cage a number of cane plants were set. Later nearly 200 stalks of cane containing tunnels of the moth borer and probably many borers were secured and put into the cage, one end of each stalk being pushed into the ground. Mr. Otto H. Swezey, entomologist of the Hawaiian Sugar Planters' Experiment Station, in September, 1917, kindly gave directions for the preparation of this cage and caused puparia of Ceromasia collected in Hawaii to be sent to the writers, who placed the adults in the cage as soon as they emerged. Eighty-seven puparia were received, from which 23 flies emerged. About half of the adults were small, but many were of normal size. Mr. Swezey's instructions were followed closely, ants were kept out of the cage, the plants were sprinkled daily, and honey and overripe fruit were provided as food for the flies.

It was found that the infestation by the moth borer in the cage was far higher than that usually found in the field. The growing plants were so heavily infested that they did not make any appreciable growth throughout the remainder of the season. Though provided with possible hosts in such numbers, the parasites did not attack the borer. Some of the cane stalks were cut open at the end of six weeks, the length of a generation of the parasite in Hawaii, but no evidence was found that they had parasitized any borers, although many live borers were found. More cane was examined later with the same negative result.

EXPERIMENT WITH A PARASITE FROM CUBA.

In 1915 the junior author went to Cuba to obtain, if possible, a tachinid parasite of the moth borer which had been reported by Mr. George N. Wolcott. It was found that while the moth borer was present, it was by no means as injurious as in Louisiana, and that the tachinid parasite *Euzenilliopsis diatraeae* Townsend evidently had much to do with its comparative control.

Living puparia of the tachinid parasite were obtained and forwarded to the senior author in New Orleans from time to time during the summer of 1915. Cages of many kinds were utilized, although none of the type which had been found satisfactory in Hawaii with tachinids was used. In every experiment the parasites died without attacking the host larvæ provided for them. Finally it was decided to release the adults in the fields at Audubon Park as soon as they emerged from the puparia. Following this action, during the next grinding season one puparium was recovered in a stalk of cane, and an adult of the species introduced from Cuba emerged from it.

No other parasites were found during the succeeding two years, and it would appear that they have died out, but the discovery of the single puparium proves that they will successfully parasitize the sugar-cane moth borer in Louisiana. It is believed by the writers that the parasite might be of much benefit in controlling the borer if it were introduced in larger numbers. If this had been possible, much might have been accomplished, but conditions in 1916 and 1917 prevented further experimental work.[1]

If the introduction of beneficial parasites can be undertaken later, it would seem advisable to station two men in Cuba to collect the parasites and one in Louisiana to receive them and ultimately to release them on the plantations. In 1915 investigations were conducted from February to September, but it appears that the most favorable season is from April to September, inclusive.

RECOMMENDATIONS.

1. Scraps of cane left about the factories and derricks after the grinding season should be destroyed by burning or otherwise. Cars in which cane is shipped, especially if they go into noninfested territory, should be kept free of such scraps.

2. Seed cane should be planted in the fall, if possible, and kept as deeply covered as practicable. Extraordinarily deep planting is not advocated, but as borer moths fail to emerge from cane under more than one-half inch of compact soil care should be taken to keep the seed cane well covered to that depth as a minimum. A heavy rain will sometimes wash the earth from the seed cane from one end of a row to the other, and in this case it is important to cover the cane again as soon as possible, especially in the spring, when the moths are emerging.

3. Cane for shipment to points beyond the infested area should be selected so as to obtain it sound and free of borers, or if this is impossible it should be soaked, previous to shipment, for at least an hour in Bordeaux mixture [2] or a solution of nicotine sulphate.[3]

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[1] Since the manuscript for this bulletin was submitted a number of sugar planters in Louisiana have agreed to contribute a small amount each to enable work in Cuba to be done. This action made it possible for the senior author to spend some time in Cuba in 1918. He collected and sent to New Orleans about 650 puparia of the tachinid *Euzenilliopsis diatraeae*, which were received and cared for by Messrs. E. R. Barber and W. G. Taggart. Several generations were reared during 1918, and it seems that the parasites will become established if they can stand the Louisiana winter.

The junior author, who was in Cuba in 1915, is no longer connected with the investigation, having accepted a position under the Federal Horticultural Board.

[2] The formula for Bordeaux mixture is as follows:

Sulphate of copper	pounds	6
Quicklime	do	4
Water	gallons	50

Dissolve the sulphate of copper in 1 gallon of hot water and slake the lime in another vessel with an equal quantity; reduce the latter to a creamy milk of lime and add slowly to the copper solution, stirring constantly. Finally, add water to make up the 50 gallons.

[3] One part nicotine sulphate (40 per cent nicotine) to 500 parts water.

4. The "trash," leaves, or "shucks" left on the fields after cutting should not be burned, but should be lightly covered with earth in the fall and plowed out in the spring. This practice has never been found to increase the borer infestation, and it has often diminished it. The soil is fertilized by the buried trash and its mechanical condition is greatly improved.

5. Cutting out "dead hearts" or dead plants and destroying them is theoretically sound, and with an abundance of cheap labor it might be recommended.

6. The introduction of parasites of the moth borer from Cuba and other tropical countries is recommended.

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